Allen-Bradley

Logix5000™ Controllers Process Control and Drives Instructions

1756-Lx, 1769-Lx, 1789-Lx, 1794-Lx, PowerFlex 700S

User Manual

Rockwell Automation

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (Publication SGI-1.1 available from your local Rockwell Automation sales office or online at http://www.ab.com/manuals/gi) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this manual.

Throughout this manual we use notes to make you aware of safety considerations.

WARNING

Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.

IMPORTANT

Identifies information that is critical for successful application and understanding of the product.

ATTENTION

Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you:

- identify a hazard
- avoid a hazard
- recognize the consequence

SHOCK HAZARD

Labels may be located on or inside the drive to alert people that dangerous voltage may be present.

BURN HAZARD

Labels may be located on or inside the drive to alert people that surfaces may be dangerous temperatures.

Introduction

This release of this document contains new and updated information. To find new and updated information, look for change bars, as shown next to this paragraph.

Updated Information

This document contains the following changes:

Change:	See:
addition of information regarding ALM deadband and rate-of-change calculations	1-4
change in how PIDE responds to the WindupHIn and WindupLIn inputs	1-46
addition of information regarding PIDE algorithms	1-54
correction to TotalTime equation	2-35
correction to real time sampling	B-9
changes to faceplate controls	appendix D

Notes:

Where to Find an Instruction

Use this locator to find the reference details about Logix instructions (the grayed-out instructions are available in other manuals). This locator also lists which programming languages are available for the instructions.

If the locator lists:	The instruction is documented in:
a page number	this manual
general	*Logix5000 Controllers General Instruction Set Reference Manual*, 1756-RM003
motion	*Logix5000 Controllers Motion Instruction Set Reference Manual,* 1756-RM007
phase	*Logix5000 Controllers PhaseManager User Manual*, LOGIX-UM001

Instruction:	Location:	Languages:
ABL ASCII Test For Buffer Line	general	relay ladder structured text
ABS Absolute Value	general	relay ladder structured text function block
ACB ASCII Chars in Buffer	general	relay ladder structured text
ACL ASCII Clear Buffer	general	relay ladder structured text
ACOS Arc Cosine	general	structured text
ACS Arc Cosine	general	relay ladder function block
ADD Add	general	relay ladder structured text function block
AFI Always False Instruction	general	relay ladder
AHL ASCII Handshake Lines	general	relay ladder structured text
ALM Alarm	1-2	structured text function block
AND Bitwise AND	general	relay ladder structured text function block
ARD ASCII Read	general	relay ladder structured text
ARL ASCII Read Line	general	relay ladder structured text
ASIN Arc Sine	general	structured text
ASN Arc Sine	general	relay ladder function block
ATAN Arc Tangent	general	structured text
ATN Arc Tangent	general	relay ladder function block
AVE File Average	general	relay ladder
AWA ASCII Write Append	general	relay ladder structured text
AWT ASCII Write	general	relay ladder structured text
BAND Boolean AND	general	structured text function block
BNOT Boolean NOT	general	structured text function block
BOR Boolean OR	general	structured text function block
BRK Break	general	relay ladder
BSL Bit Shift Left	general	relay ladder
BSR Bit Shift Right	general	relay ladder
BTD Bit Field Distribute	general	relay ladder
BTDT Bit Field Distribute with Target	general	structured text function block
BTR Message	general	relay ladder structured text
BTW Message	general	relay ladder structured text
BXOR Boolean Exclusive OR	general	structured text function block
CLR Clear	general	relay ladder structured text

Instruction:	Location:	Languages:
CMP Compare	general	relay ladder
CONCAT String Concatenate	general	relay ladder structured text
COP Copy File	general	relay ladder structured text
COS Cosine	general	relay ladder structured text function block
CPS Synchronous Copy File	general	relay ladder structured text
CPT Compute	general	relay ladder
CTD Count Down	general	relay ladder
CTU Count Up	general	relay ladder
CTUD Count Up/Down	general	structured text function block
D2SD Discrete 2-State Device	1-7	structured text function block
D3SD Discrete 3-State Device	1-16	structured text function block
DDT Diagnostic Detect	general	relay ladder
DEDT Deadtime	1-29	structured text function block
DEG Degrees	general	relay ladder structured text function block
DELETE String Delete	general	relay ladder structured text
DERV Derivative	3-2	structured text function block
DFF D Flip-Flop	6-2	structured text function block
DIV Divide	general	relay ladder structured text function block
DTOS DINT to String	general	relay ladder structured text
DTR Data Transitional	general	relay ladder
EOT End of Transition	general	relay ladder structured text
EQU Equal to	general	relay ladder structured text function block

Instruction:	Location:	Languages:
ESEL Enhanced Select	4-2	structured text function block
EVENT Trigger Event Task	general	relay ladder structured text
FAL File Arithmetic and Logic	general	relay ladder
FBC File Bit Comparison	general	relay ladder
FFL FIFO Load	general	relay ladder
FFU FIFO Unload	general	relay ladder
FGEN Function Generator	1-34	structured text function block
FIND Find String	general	relay ladder structured text
FLL File Fill	general	relay ladder
FOR For	general	relay ladder
FRD Convert to Integer	general	relay ladder function block
FSC File Search and Compare	general	relay ladder
GEQ Greater than or Equal to	general	relay ladder structured text function block
GRT Greater Than	general	relay ladder structured text function block
GSV Get System Value	general	relay ladder structured text
HLL High/Low Limit	4-9	structured text function block
HPF High Pass Filter	3-6	structured text function block
ICON Input Wire Connector	B-1	function block
INSERT Insert String	general	relay ladder structured text
INTG Integrator		structured text function block
IOT Immediate Output	general	relay ladder structured text
IREF Input Reference	B-1	function block
JKFF JK Flip-Flop	6-4	structured text function block

Instruction:	Location:	Languages:
JMP Jump to Label	general	relay ladder
JSR Jump to Subroutine	general	relay ladder structured text function block
JXR Jump to External Routine	general	relay ladder
LBL Label	general	relay ladder
LDL2 Second-Order Lead Lag	3-12	structured text function block
LDLG Lead-Lag	1-38	structured text function block
LEQ Less Than or Equal to	general	relay ladder structured text function block
LES Less Than	general	relay ladder structured text function block
LFL LIFO Load	general	relay ladder
LFU LIFO Unload	general	relay ladder
LIM Limit	general	relay ladder function block
LN Natural Log	general	relay ladder structured text function block
LOG Log Base 10	general	relay ladder structured text function block
LOWER Lower Case	general	relay ladder structured text
LPF Low Pass Filter	3-18	structured text function block
MAAT Motion Apply Axis Tuning	motion	relay ladder structured text
MAFR Motion Axis Fault Reset	motion	relay ladder structured text
MAG Motion Axis Gear	motion	relay ladder structured text
MAH Motion Axis Home	motion	relay ladder structured text
MAHD Motion Apply Hookup Diagnostics	motion	relay ladder structured text
MAJ Motion Axis Jog	motion	relay ladder structured text

Instruction:	Location:	Languages:
MAM Motion Axis Move	motion	relay ladder structured text
MAOC Motion Arm Output Cam	motion	relay ladder structured text
MAPC Motion Axis Position Cam	motion	relay ladder structured text
MAR Motion Arm Registration	motion	relay ladder structured text
MAS Motion Axis Stop	motion	relay ladder structured text
MASD Motion Axis Shutdown	motion	relay ladder structured text
MASR MMotion Axis Shutdown Reset	motion	relay ladder structured text
MATC Motion Axis Time Cam	motion	relay ladder structured text
MAVE Moving Average	5-2	structured text function block
MAW Motion Arm Watch	motion	relay ladder structured text
MAXC Maximum Capture	5-6	structured text function block
MCCP Motion Calculate Cam Profile	motion	relay ladder structured text
MCD Motion Change Dynamics	motion	relay ladder structured text
MCR Master Control Reset	general	relay ladder
MDF Motion Direct Drive Off	motion	relay ladder structured text
MDO Motion Direct Drive On	motion	relay ladder structured text
MDOC Motion Disarm Output Cam	motion	relay ladder structured text
MDR Motion Disarm Registration	motion	relay ladder structured text
MDW Motion Disarm Watch	motion	relay ladder structured text
MEQ Mask Equal to	general	relay ladder structured text function block
MGS Motion Group Stop	motion	relay ladder structured text
MGSD Motion Group Shutdown	motion	relay ladder structured text

Instruction:	Location:	Languages:
MGSP Motion Group Strobe Position	motion	relay ladder structured text
MGSR Motion Group Shutdown Reset	motion	relay ladder structured text
MID Middle String	general	relay ladder structured text
MINC Minimum Capture	5-8	structured text function block
MOD Modulo	general	relay ladder structured text function block
MOV Move	general	relay ladder
MRAT Motion Run Axis Tuning	motion	relay ladder structured text
MRHD Motion Run Hookup Diagnostics	motion	relay ladder structured text
MRP Motion Redefine Position	motion	relay ladder structured text
MSF Motion Servo Off	motion	relay ladder structured text
MSG Message	general	relay ladder structured text
MSO Motion Servo On	motion	relay ladder structured text
MSTD Moving Standard Deviation	5-10	structured text function block
MUL Multiply	general	relay ladder structured text function block
MUX Multiplexer	4-12	function block
MVM Masked Move	general	relay ladder
MVMT Masked Move with Target	general	structured text function block
NEG Negate	general	relay ladder structured text function block
NEQ Not Equal to	general	relay ladder structured text function block
NOP No Operation	general	relay ladder
NOT Bitwise NOT	general	relay ladder structured text function block

Instruction:	Location:	Languages:
NTCH Notch Filter	3-24	structured text function block
OCON Output Wire Connector	B-1	function block
ONS One Shot	general	relay ladder
OR Bitwise OR	general	relay ladder structured text function block
OREF Output Reference	B-1	function block
OSF One Shot Falling	general	relay ladder
OSFI One Shot Falling with Input	general	structured text function block
OSR One Shot Rising	general	relay ladder
OSRI One Shot Rising with Input	general	structured text function block
OTE Output Energize	general	relay ladder
OTL Output Latch	general	relay ladder
OTU Output Unlatch	general	relay ladder
PATT Attach to Equipment Phase	phase	relay ladder structured text
PCLF Equipment Phase Clear Failure	phase	relay ladder structured text
PCMD Equipment Phase Command	phase	relay ladder structured text
PDET Detach from Equipment Phase	phase	relay ladder structured text
PFL Equipment Phase Failure	phase	relay ladder structured text
PI Proportional + Integral	2-8	structured text function block
PID Proportional Integral Derivative	general	relay ladder structured text
PIDE Enhanced PID	1-42	structured text function block
PMUL Pulse Multiplier	2-20	structured text function block
POSP Position Proportional	1-77	structured text function block

Instruction:	Location:	Languages:
POVR Equipment Phase Override Command	phase	relay ladder structured text
PPD Equipment Phase Paused	phase	relay ladder structured text
PRNP Equipment Phase New Parameters	phase	relay ladder structured text
PSC Phase State Complete	phase	relay ladder structured text
PXRQ Equipment Phase External Request	phase	relay ladder structured text
RAD Radians	general	relay ladder structured text function block
RES Reset	general	relay ladder
RESD Reset Dominant	6-6	structured text function block
RET Return	general	relay ladder structured text function block
RLIM Rate Limiter	4-15	structured text function block
RMPS Ramp/Soak	1-84	structured text function block
RTO Retentive Timer On	general	relay ladder
RTOR Retentive Timer On with Reset	general	structured text function block
RTOS REAL to String	general	relay ladder structured text
SBR Subroutine	general	relay ladder structured text function block
SCL Scale	1-98	structured text function block
SCRV S-Curve	2-28	structured text function block
SEL Select	4-19	function block
SETD Set Dominant	6-8	structured text function block
SFP SFC Pause	general	relay ladder structured text
SFR SFC Reset	general	relay ladder structured text

Instruction:	Location:	Languages:
SIN Sine	general	relay ladder structured text function block
SIZE Size In Elements	general	relay ladder structured text
SNEG Selected Negate	4-21	structured text function block
SOC Second-Order Controller	2-38	structured text function block
SQI Sequencer Input	general	relay ladder
SQL Sequencer Load	general	relay ladder
SQO Sequencer Output	general	relay ladder
SQR Square Root	general	relay ladder function block
SQRT Square Root	general	structured text
SRT File Sort	general	relay ladder structured text
SRTP Split Range Time Proportional	1-102	structured text function block
SSUM Selected Summer	4-23	structured text function block
SSV Set System Value	general	relay ladder structured text
STD File Standard Deviation	general	relay ladder
STOD String To DINT	general	relay ladder structured text
STOR String To REAL	general	relay ladder structured text
SUB Subtract	general	relay ladder structured text function block
SWPB Swap Byte	general	relay ladder structured text
TAN Tangent	general	relay ladder structured text function block
TND Temporary End	general	relay ladder
TOD Convert to BCD	general	relay ladder function block
TOF Timer Off Delay	general	relay ladder

Instruction:	Location:	Languages:
TOFR Timer Off Delay with Reset	general	structured text function block
TON Timer On Delay	general	relay ladder
TONR Timer On Delay with Reset	general	structured text function block
TOT Totalizer	1-108	structured text function block
TRN Truncate	general	relay ladder function block
TRUNC Truncate	general	structured text
UID User Interrupt Disable	general	relay ladder structured text
UIE User Interrupt Enable	general	relay ladder structured text
UPDN Up/Down Accumulator	2-47	structured text function block
UPPER Upper Case	general	relay ladder structured text
XIC Examine If Closed	general	relay ladder
XIO Examine If Open	general	relay ladder
XOR Bitwise Exclusive OR	general	relay ladder structured text function block
XPY X to the Power of Y	general	relay ladder structured text function block

Preface

Introduction

This manual is one of several Logix-based instruction documents.

Task/Goal:	Documents:
Programming the controller for sequential applications	*Logix5000 Controllers General Instructions Reference Manual*, publication 1756-RM003
Programming the controller for process or drives applications **You are here**	*Logix5000 Controllers Process Control and Drives Instructions Reference Manual*, publication 1756-RM006
Programming the controller for motion applications	*Logix5000 Controllers Motion Instructions Reference Manual,* publication 1756-RM007
Importing a text file or tags into a project	*Logix5000 Controller Import/Export Reference Manual*, publication 1756-RM084
Exporting a project or tags to a text file	
Converting a PLC-5 or SLC 500 application to a Logix5000 application	*Logix5550 Controller Converting PLC-5 or SLC 500 Logic to Logix5000 Logic Reference Manual*, publication 1756-RM085

These core documents address the Logix5000 family of controllers:

If you are:	Use this publication:
a new user of a Logix5000 controller This quick start provides a visual, step-by-step overview of the basic steps you need to complete to get you controller configured and running.	*Logix5000 Controllers Quick Start* publication 1756-QS001
an experienced user of Logix5000 controllers This design reference provides considerations when planning and implementing a Logix5000 control system.	*Logix5000 Controllers Design Considerations Reference Manual* publication 1756-QR107
an experienced user of Logix5000 controllers This system reference provides a high-level listing of configuration information, controller features, and instructions (ladder relay, function block diagram, and structured text).	*Logix5000 Controllers System Reference* publication 1756-QR107
any user of a Logix5000 controller This common procedures manual explains the common features and functions of all Logix5000 controllers.	*Logix5000 Controllers Common Procedures* publication 1756-PM001

Who Should Use This Manual

This document provides a programmer with details about each available instruction for a Logix-based controller. You should already be familiar with how the Logix-based controller stores and processes data.

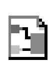
Novice programmers should read all the details about an instruction before using the instruction. Experienced programmers can refer to the instruction information to verify details.

Purpose of This Manual

This manual provides a description of each instruction in this format.

This section:	Provides this type of information:
Instruction name	identifies the instruction defines whether the instruction is an input or an output instruction
Operands	lists all the operands of the instruction  if available in relay ladder, describes the operands  if available in structured text, describes the operands  if available in function block, describes the operands The pins shown on a default function block are only the default pins. The operands table lists all the possible pins for a function block.
Instruction structure	lists control status bits and values, if any, of the instruction
Description	describes the instruction's use defines any differences when the instruction is enabled and disabled, if appropriate
Arithmetic status flags	defines whether or not the instruction affects arithmetic status flags see appendix Common Attributes
Fault conditions	defines whether or not the instruction generates minor or major faults if so, defines the fault type and code
Execution	defines the specifics of how the instruction operates
Example	provides at least one programming example in each available programming language includes a description explaining each example

The following icons help identify language specific information:

This icon:	Indicates this programming language:
	relay ladder
	structured text
	function block

Common Information for All Instructions

The Logix5000 instruction set has some common attributes:

For this information:	See this appendix:
common attributes	appendix Common Attributes defines: • arithmetic status flags • data types • keywords
arrays	appendix Array Concepts defines arrays and explains how the controller manipulates arrays
function block attributes	appendix Function Block Attributes defines: • program and operator control • timing modes

Conventions and Related Terms

Set and clear

This manual uses set and clear to define the status of bits (booleans) and values (non-booleans):

This term:	Means:
set	the bit is set to 1 (ON) a value is set to any non-zero number
clear	the bit is cleared to 0 (OFF) all the bits in a value are cleared to 0

If an operand or parameter supports more than one data type, the bold data types indicate optimal data types. An instruction executes faster and requires less memory if all the operands of the instruction use the same optimal data type, typically DINT or REAL.

Relay ladder rung condition

The controller evaluates ladder instructions based on the rung condition preceding the instruction (rung-condition-in). Based on the rung-condition-in and the instruction, the controller sets the rung condition following the instruction (rung-condition-out), which in turn, affects any subsequent instruction.

If the rung-in condition to an input instruction is true, the controller evaluates the instruction and sets the rung-out condition based on the results of the instruction. If the instruction evaluates to true, the rung-out condition is true; if the instruction evaluates to false, the rung-out condition is false.

The controller also prescans instructions. Prescan is a special scan of all routines in the controller. The controller scans all main routines and subroutines during prescan, but ignores jumps that could skip the execution of instructions. The controller executes all FOR loops and subroutine calls. If a subroutine is called more than once, it is executed each time it is called. The controller uses prescan of relay ladder instructions to reset non-retentive I/O and internal values.

During prescan, input values are not current and outputs are not written. The following conditions generate prescan:

- Toggle from Program to Run mode
- Automatically enter Run mode from a power-up condition.

Prescan does not occur for a program when:

- The program becomes scheduled while the controller is running.
- The program is unscheduled when the controller enters Run mode.

Function block states

The controller evaluates function block instructions based on the state of different conditions.

Possible Condition:	Description:
prescan	Prescan for function block routines is the same as for relay ladder routines. The only difference is that the EnableIn parameter for each function block instruction is cleared during prescan.
instruction first scan	Instruction first scan refers to the first time an instruction is executed after prescan. The controller uses instruction first scan to read current inputs and determine the appropriate state to be in.
instruction first run	Instruction first run refers to the first time the instruction executes with a new instance of a data structure. The controller uses instruction first run to generate coefficients and other data stores that do not change for a function block after initial download.

Every function block instruction also includes EnableIn and EnableOut parameters:

- function block instructions execute normally when EnableIn is set.
- when EnableIn is cleared, the function block instruction either executes prescan logic, postscan logic, or just skips normal algorithm execution.
- EnableOut mirrors EnableIn, however, if function block execution detects an overflow condition EnableOut is also cleared.
- function block execution resumes where it left off when EnableIn toggles from cleared to set. However there are some function block instructions that specify special functionality, such as re-initialzation, when EnableIn toggles from cleared to set. For function block instructions with time base parameters, whenever the timing mode is Oversample, the instruction always resumes were it left off when EnableIn toggles from cleared to set.

If the EnableIn parameter is not wired, the instruction always executes as normal and EnableIn remains set. If you clear EnableIn, it changes to set the next time the instruction executes.

IMPORTANT	When programming in function block, restrict the range of engineering units to $+/-10^{+/-15}$ because internal floating point calculations are done using single precision floating point. Engineering units outside of this range may result in a loss of accuracy if results approach the limitations of single precision floating point ($+/-10^{+/-38}$).

Process Control Instructions (ALM, D2SD, D3SD, DEDT, FGEN, LDLG, PIDE, POSP, RMPS, SCL, SRTP, TOT)

Chapter 1

Chapter 2

Drives Instructions (INTG, PI, PMUL, SCRV, SOC, UPDN)

Chapter 3

Filter Instructions (DERV, HPF, LDL2, LPF, NTCH)

Chapter 4

Select/Limit Instructions (ESEL, HLL, MUX, RLIM, SEL, SNEG, SSUM)

Chapter 5

Statistical Instructions (MAVE, MAXC, MINC, MSTD)

Chapter 6

Move/Logical Instructions (DFF, JKFF, RESD, SETD)

Appendix A

Common Attributes

Appendix B

Function Block Attributes

Appendix C

Structured Text Programming

Appendix D

Function Block Faceplate Controls

Notes:

Process Control Instructions
(ALM, D2SD, D3SD, DEDT, FGEN, LDLG, PIDE, POSP, RMPS, SCL, SRTP, TOT)

Introduction

These process control instruction are available:

If you want to:	Use this instruction:	Available in these languages:	See page:
provide alarming for any analog signal.	Alarm (ALM)	structured text function block	1-2
control discrete devices, such as solenoid valves, pumps, and motors, that have only two possible states such as on/off, open/closed, etc.	Discrete 2-State Device (D2SD)	structured text function block	1-7
control discrete devices, such as high/low/off feeders, that have three possible states such as fast/slow/off, forward/stop/reverse, etc.	Discrete 3-State Device (D3SD)	structured text function block	1-16
perform a delay of a single input. You select the amount of deadtime delay.	Deadtime (DEDT)	structured text function block	1-29
convert an input based on a piece-wise linear function.	Function Generator (FGEN)	structured text function block	1-34
provide a phase lead-lag compensation for an input signal.	Lead-Lag (LDLG)	structured text function block	1-38
regulate an analog output to maintain a process variable at a certain setpoint using a PID algorithm.	Enhanced PID (PIDE)	structured text function block	1-42
raise/lower or open/close a device, such as a motor-operated valve, by pulsing open or close contacts.	Position Proportional (POSP)	structured text function block	1-77
provide for alternating ramp and soak periods to follow a temperature profile.	Ramp/Soak (RMPS)	structured text function block	1-84
convert an unscaled input value to a floating point value in engineering units.	Scale (SCL)	structured text function block	1-98
take the 0-100% output of a PID loop and drive heating and cooling digital output contacts with a periodic pulse.	Split Range Time Proportional (SRTP)	structured text function block	1-102
provide a time-scaled accumulation of an analog input value, such as a volumetric flow.	Totalizer (TOT)	structured text function block	1-108

Alarm (ALM)

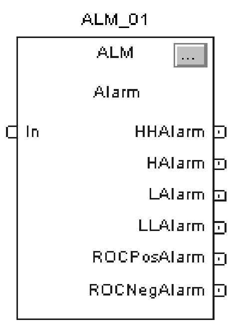
The ALM instruction provides alarming for any analog signal.

Operands:

```
ALM(ALM_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
ALM tag	ALARM	structure	ALM structure



Function Block

Operand:	Type:	Format:	Description:
ALM tag	ALARM	structure	ALM structure

ALARM Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction always executes.
In	REAL	The analog signal input. Valid = any float Default = 0.0
HHLimit	REAL	The high-high alarm limit for the input. Valid = any real value Default = maximum positive value
HLimit	REAL	The high alarm limit for the input. Valid = any real value Default = maximum positive value
LLimit	REAL	The low alarm limit for the input. Valid = any real value. Default = maximum negative value
LLLimit	REAL	The low-low alarm limit for the input. Valid = any real value Default = maximum negative value
Deadband	REAL	The alarm deadband for the high-high to low-low limits. Valid = any real value ≥ 0.0 Default = 0.0

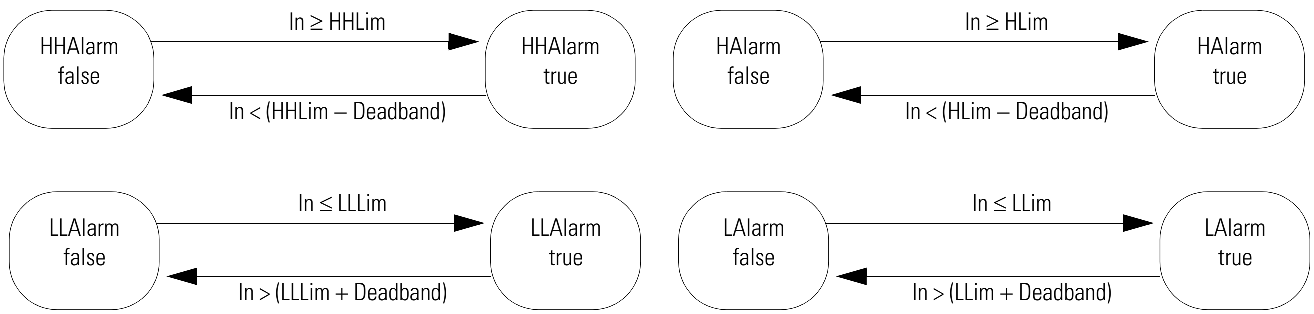
Input Parameter:	Data Type:	Description:
ROCPosLimit	REAL	The rate-of-change alarm limit in units per second for a positive (increasing) change in the input. Set ROCPosLimit = 0 to disable ROC positive alarming. If invalid, the instruction assumes a value of 0.0 and sets the appropriate bit in Status. Valid = any real value ≥ 0.0 Default = 0.0
ROCNegLimit	REAL	The rate-of-change alarm limit in units per second for a negative (decreasing) change in the input. Set ROCPNegLimit = 0 to disable ROC negative alarming. If invalid, the instruction assumes a value of 0.0 and sets the appropriate bit in Status. Valid = any real value ≥ 0.0 Default = 0.0
ROCPeriod	REAL	The time period used to evaluate the rate-of-change alarms (in seconds). Set ROCPeriod = 0 to disable ROC alarming and set the output ROC to zero. If invalid, the instruction assumes a value of 0.0 and sets the appropriate bit in Status. Valid = any real value ≥ 0.0 Default = 0.0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
HHAlarm	BOOL	The high-high alarm indicator. Default = false
HAlarm	BOOL	The high alarm indicator. Default = false
LAlarm	BOOL	The low alarm indicator. Default = false
LLAlarm	BOOL	The low-low alarm indicator. Default = false
ROCPosAlarm	BOOL	The rate-of-change positive alarm indicator. Default = false
ROCNegAlarm	BOOL	The rate-of-change negative alarm indicator. Default = false
ROC	REAL	The rate-of-change output. Arithmetic status flags are set for this output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
DeadbandInv (Status.1)	BOOL	Invalid Deadband value.
ROCPosLimitInv (Status.2)	BOOL	Invalid ROCPosLimit value.
ROCNegLimitInv (Status.3)	BOOL	Invalid ROCNegLimit value.
ROCPeriodInv (Status.4)	BOOL	Invalid ROCPeriod value.

Description: The ALM instruction provides alarm indicators for high-high, high, low, low-low, rate-of-change positive, and rate-of-change negative. An alarm deadband is available for the high-high to low-low alarms. A user defined period for performing rate-of-change alarming is also available.

High-high to low-low alarm

The high-high and low-low alarm algorithms compare the input to the alarm limit and the alarm limit plus or minus the deadband.



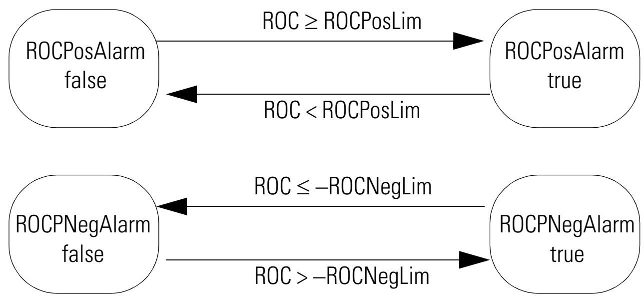
Rate-of-change alarm

The rate-of-change (ROC) alarm compares the change of the input over the ROCPeriod to the rate-of-change limits. The ROCPeriod provides a type of deadband for the rate-of-change alarm. For example, define an ROC alarm limit of 2°F/second with a period of execution of 100 ms. If you use an analog input module with a resolution of 1°F, every time the input value changes, an ROC alarm is generated because the instruction calculates an effective rate of 10°F/second. However, enter an ROCPeriod of 1 sec and the instruction only generates an alarm if the rate truly exceeds the 2°F/second limit.

The ROC alarm calculates the rate-of-change as:

$$ROC = \frac{In(Now) - In(EndofpreviousROCPeriod)}{ROCPeriod}$$

The instruction performs this calculation when the ROCPeriod expires. Once the instruction calculates the ROC, it determines alarms as:



Monitoring the ALM instruction

There is an operator faceplate available for the ALM instruction. For more information, see appendix Function Block Faceplate Controls.

Arithmetic Status Flags: Arithmetic status flags are set for the ROC output.

Fault Conditions: none

Execution:

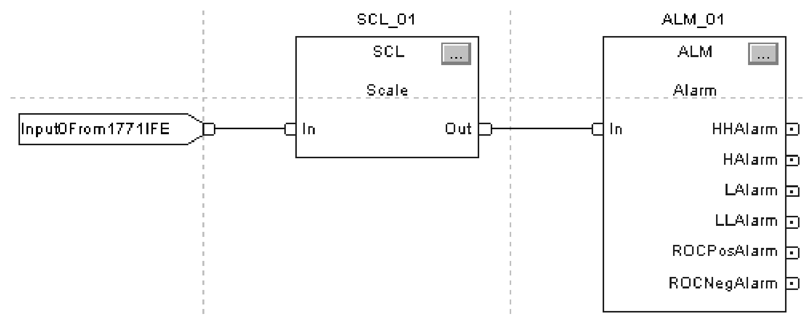
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	All alarm outputs are cleared. The elapsed time accumulator is cleared.	All alarm outputs are cleared. The elapsed time accumulator is cleared.
instruction first run	All alarm outputs are cleared. The elapsed time accumulator is cleared.	All alarm outputs are cleared. The elapsed time accumulator is cleared.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The ALM instruction is typically used either with analog input modules (such as 1771 I/O modules) that do not support on-board alarming or to generate alarms on a calculated variable. In this example, an analog input from a 1771-IFE module is first scaled to engineering units using the SCL instruction. The *Out* of the SCL instruction is an input to the ALM instruction to determine whether to set an alarm. The resulting alarm output parameters could then be used in your program and/or viewed on an operator interface display.

Structured Text

```
SCL_01.In := Input0From1771IFE;
SCL(SCL_01);

ALM_01.In := SCL_01.Out;
ALARM(ALM_01);
```

Function Block



Discrete 2-State Device (D2SD)

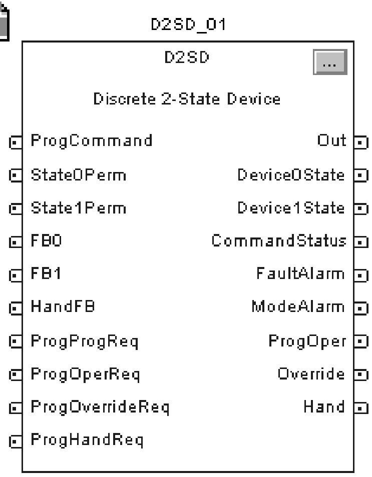
The D2SD instruction controls a discrete device which has only two possible states such as on/off, open/closed, etc.

Operands:

```
D2SD(D2SD_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
D2SD tag	DISCRETE_2STATE	structure	D2SD structure



Function Block

Operand:	Type:	Format:	Description:
D2SD tag	DISCRETE_2STATE	structure	D2SD structure

DISCRETE_2STATE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
ProgCommand	BOOL	Used to determine CommandStatus when the device is in Program control. When set, the device is commanded to the 1 state; when cleared, the device is commanded to the 0 state. Default is cleared.
Oper0Req	BOOL	Operator state 0 request. Set by the operator interface to place the device in the 0 state when the device is in Operator control. Default is cleared.
Oper1Req	BOOL	Operator state 1 request. Set by the operator interface to place the device in the 1 state when the device is in Operator control. Default is cleared.
State0Perm	BOOL	State 0 permissive. Unless in Hand or Override mode, this input must be set for the device to enter the 0 state. This input has no effect for a device already in the 0 state. Default is set.

Input Parameter:	Data Type:	Description:
State1Perm	BOOL	State 1 permissive. Unless in the Hand or Override mode, this input must be set for the device to enter the 1 state. This input has no effect for a device already in the 1 state. Default is set.
FB0	BOOL	The first feedback input available to the D2SD instruction. Default is cleared.
FB1	BOOL	The second feedback input available to the D2SD instruction. Default is cleared.
HandFB	BOOL	Hand feedback input. This input is from a field hand/off/auto station and it shows the requested state of the field device. When set, the field device is being requested to enter the 1 state; when cleared, the field device is being requested to enter the 0 state. Default is cleared.
FaultTime	REAL	Fault time value. Configure the value in seconds of the time to allow the device to reach a newly commanded state. Set FaultTime = 0 to disable the fault timer. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = any float $\geq$ 0.0 Default = 0.0
FaultAlarmLatch	BOOL	Fault alarm latch input. When set and FaultAlarm is set, latch FaultAlarm. To unlatch FaultAlarm set FaultAlmUnlatch or clear FaultAlarmLatch. Default is cleared.
FaultAlmUnLatch	BOOL	Fault alarm unlatch input. Set FaultAlmUnLatch when FaultAlarmLatch is set to unlatch FaultAlarm. The instruction clears this input. Default is cleared.
OverrideOnInit	BOOL	Override on initialization request. If this bit is set, then during instruction first scan, the 2-state device is placed in Operator control, Override is set, and Hand is cleared. If ProgHandReq is set, then Override is cleared and Hand is set. Default is cleared.
OverrideOnFault	BOOL	Override on fault request. Set OverrideOnFault if the device should go to Override mode and enter the OverrideState on a fault alarm. After the fault alarm is removed, the 2-state device is placed in Operator control. Default is cleared.
OutReverse	BOOL	Reverse default out state. The default state of Out is cleared when commanded to state 0, and set when commanded to state 1. When OutReverse is set, Out is set when commanded to state 0, and cleared when commanded to state 1. Default is cleared.
OverrideState	BOOL	Override state input. Configure this value to specify the state of the device when the device is in Override mode. Set indicates that the device should go to the 1 state; cleared indicates that the device should go to the 0 state. Default is cleared.
FB0State0	BOOL	Feedback 0 state 0 input. Configure the state of the FB0 when the device is in the 0 state. Default is cleared.
FB0State1	BOOL	Feedback 0 state 1 input. Configure the state of the FB0 when the device is in the 1 state. Default is cleared.
FB1State0	BOOL	Feedback 1 state 0 input. Configure the state of the FB1 when the device is in the 0 state. Default is cleared.
FB1State1	BOOL	Feedback 1 state 1 input. Configure the state of the FB1 when the device is in the 1 state. Default is cleared.

Input Parameter:	Data Type:	Description:
ProgProgReq	BOOL	Program program request. Set by the user program to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction into Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set by the user program to request Operator control. Holding this set locks the instruction into Operator control. Default is cleared.
ProgOverrideReq	BOOL	Program override request. Set by the user program to request the device to enter Override mode. Ignored if ProgHandReq is set. Default is cleared.
ProgHandReq	BOOL	Program hand request. Set by the user program to request the device to enter Hand mode. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input. Default is cleared.
OperOperReq	BOOL	Operator operator request. Set by the operator interface to request Operator control. The instruction clears this input. Default is cleared.
ProgValueReset	BOOL	Reset program control values. When set, all the program request inputs are cleared each execution of the instruction. Default is cleared.

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	BOOL	The output of the 2-state instruction.
Device0State	BOOL	Device 0 state output. Set when the device is commanded to the 0 state and the feedbacks indicate the device really is in the 0 state.
Device1State	BOOL	Device 1 state output. Set when the device is commanded to the 1 state and the feedbacks indicate the device really is in the 1 state.
CommandStatus	BOOL	Command status output. Set when the device is being commanded to the 1 state and cleared when the device is being commanded to the 0 state.
FaultAlarm	BOOL	Fault alarm output. Set if the device was commanded to a new state and the FaultTime has expired without the feedbacks indicating that the new state has actually been reached. Also set if, after reaching a commanded state, the feedbacks suddenly indicate that the device is no longer in the commanded state.
ModeAlarm	BOOL	Mode alarm output. Set if the device is in Operator control and a program command changes to a state which is different from the state currently commanded by the operator. This alarm is intended as a reminder that a device was left in Operator control.
ProgOper	BOOL	Program/Operator control indicator. Set when in Program control. Cleared when in Operator control.
Override	BOOL	Override mode. Set when the device is in the Override mode.
Hand	BOOL	Hand mode. Set when the device is in the Hand mode.
Status	DINT	Status of the function block.

Output Parameter:	Data Type:	Description:
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
FaultTimeInv (Status.1)	BOOL	Invalid FaultTime value. The instruction sets FaultTime = 0.
OperReqInv (Status.2)	BOOL	Both operator state request bits are set.

Description: The D2SD instruction controls a discrete device which has only two possible states such as on/off, open/closed, etc. Typical discrete devices of this nature include motors, pumps, and solenoid valves.

Monitoring the D2SD instruction

There is an operator faceplate available for the D2SD instruction. For more information, see appendix Function Block Faceplate Controls.

Arithmetic Status Flags: Arithmetic status flags are not affected.

Fault Conditions: none

Execution:

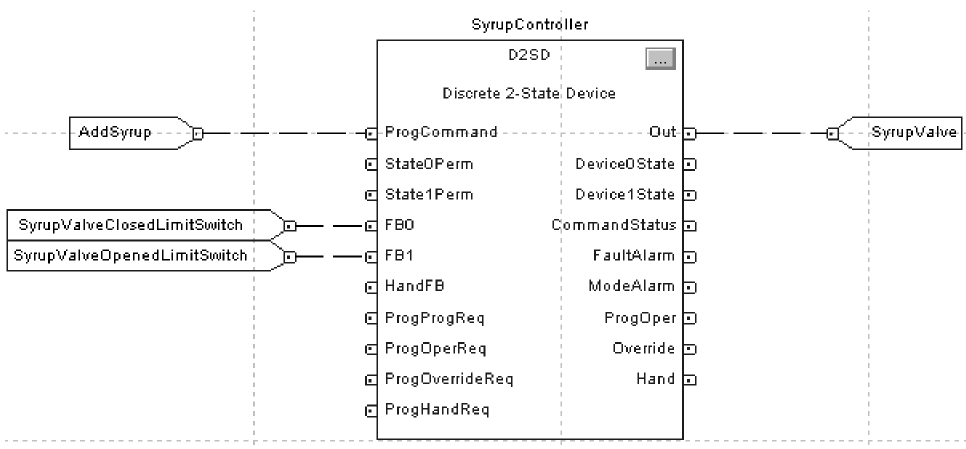
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	The fault timer is cleared. ModeAlarm is cleared. All the operator request inputs are cleared. If ProgValueReset is set, all the program request inputs are cleared. When OverrideOnInit is set, ProgOper is cleared (Operator control). If ProgHandReq is cleared and OverrideOnInit is set, clear Hand and set Override (Override mode). If ProgHandReq is set, set Hand and clear Override (Hand mode).	
instruction first run	ProgOper and CommandStatus are cleared.	ProgOper and CommandStatus are cleared.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The D2SD instruction is typically used to control on-off or open-close devices such as pumps or solenoid valves. In this example, the D2SD instruction controls a solenoid valve adding corn syrup to a batch tank. As long as the D2SD instruction is in Program control, the valve opens when the AddSyrup input is set. The operator can also take Operator control of the valve to open or close it if necessary. The solenoid valve in this example has limit switches that indicate when the valve is fully closed or opened. These switches are wired into the FB0 and FB1 feedback inputs. This allows the D2SD instruction to generate a *FaultAlarm* if the solenoid valve does not reach the commanded state within the configured *FaultTime*.

Structured Text

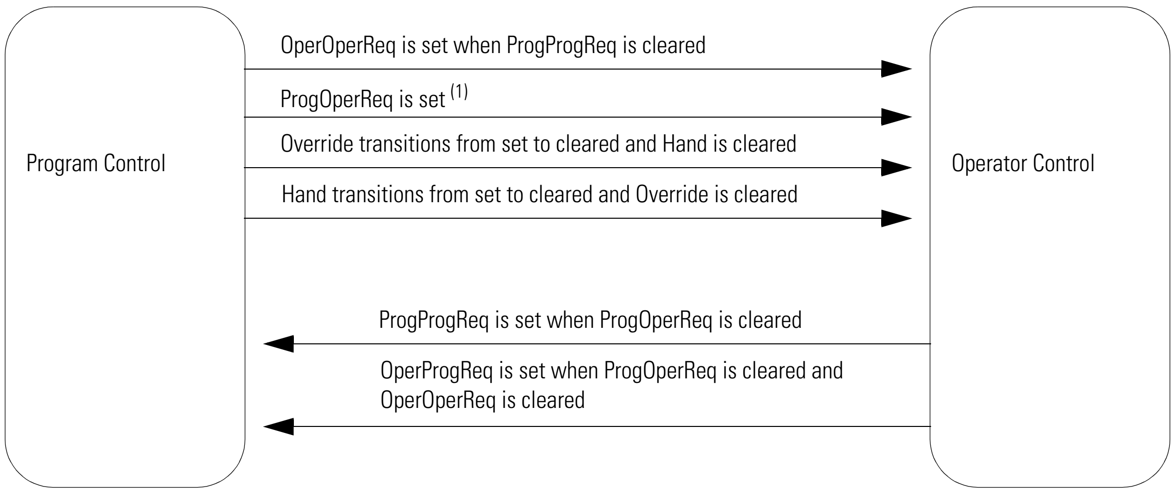
```
SyrupController.ProgCommand := AddSyrup;
SyrupController.FB0 := SyrupValveClosedLimitSwitch;
SyrupController.FB1 := SyrupValveOpenedLimitSwitch;
D2SD(SyrupController);

SyrupValve := SyrupController.Out;
```

Function Block



Switching between Program control and Operator control

The following diagram shows how the D2SD instruction changes between Program control and Operator control.

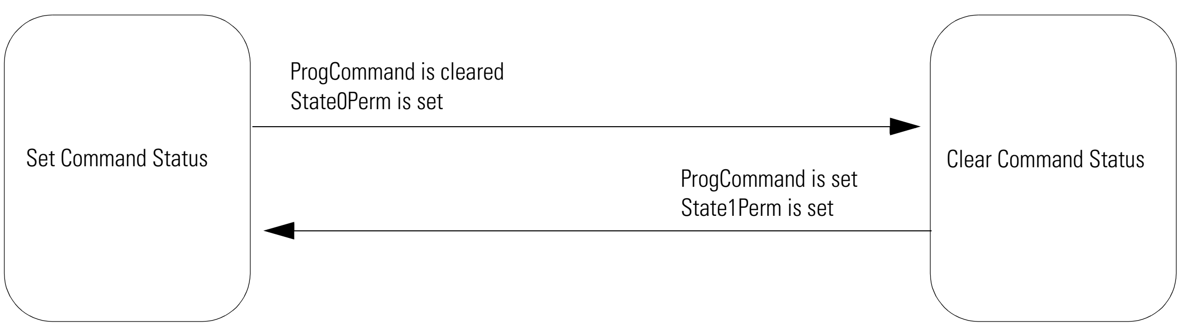


(1) The instruction remains in Operator control mode when ProgOperReq is set.

For more information on program and operator control, see page B-13.

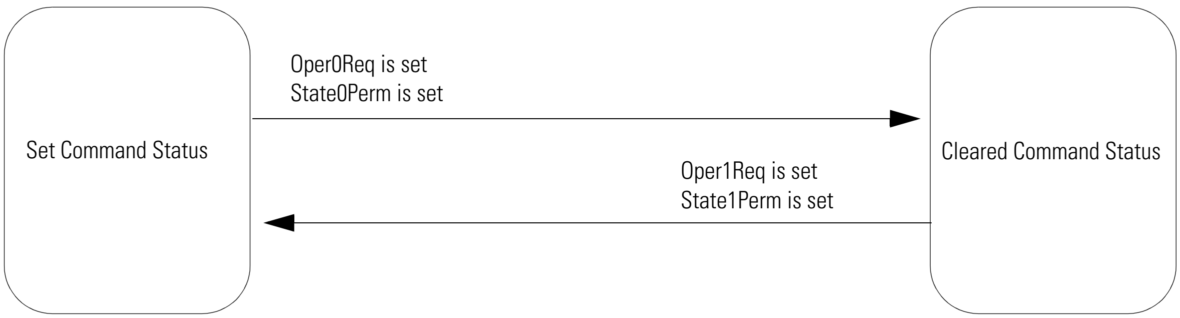
Commanded state in Program control

The following diagram illustrates how the D2SD instruction operates when in Program control.



Commanded state in Operator control

The following diagram illustrates how the D2SD instruction operates when in Operator control.



If both Oper0Req and Oper1Req are set:

- the instruction sets the appropriate bit in Status
- if Override and Hand are cleared, the instruction holds the previous state.

After every instruction execution, the instruction:

- clears all the operator request inputs
- if ProgValueReset is set, clears all the program request inputs

Hand mode or Override mode

The following table describes how the D2SD instruction determines whether to operate in Hand or Override mode

ProgHandReq:	ProgOverrideReq:	FaultAlarm and OverrideOnFault:	Description:
set	either	either	Hand mode Hand is set Override is cleared
cleared	set	either	Override mode Hand is cleared Override is set
cleared	either	set	Override mode Hand is cleared Override is set

When the instruction is in Override mode, CommandStatus = OverrideState

When the instruction is in Hand mode, CommandStatus = HandFB

Output state

The D2SD output state is based on the state of the command status.

CommandStatus:	Output state:
cleared	if OutReverse is cleared, Out is cleared if OutReverse is set, Out is set
set	if OutReverse is cleared, Out is set if OutReverse is set, Out is cleared
cleared **and** FB0 = FB0State0 **and** FB1 = FB1State0	the fault timer is stopped and cleared Device0State is set
set **and** FB0 = FB0State1 **and** FB1 = FB1State1	the fault timer is stopped and cleared Device1State is set

Fault alarm conditions

The D2SD instruction checks for these fault alarm conditions.

Fault alarm condition resulting from:	Rules:
device state was commanded to change, but the feedback did not indicate that the desired state was actually reached within the FaultTime.	Start the fault timer when $CommandStatus_n \neq CommandStatus_{n-1}$ Set FaultAlarm when fault timer is done and FaultTime > 0.0
the device unexpectedly leaving a state (according to the feedback) without being commanded to.	Set FaultAlarm when the fault timer is not timing and one of the following conditions is satisfied: CommandStatus is cleared and Device0State is cleared CommandStatus is set and Device1State is cleared

FaultAlarm is cleared if one of the following conditions is met:

- CommandStatus is cleared and Device0State is set
- CommandStatus is set and Device1State is set
- FaultTime ≤ 0

FaultAlarm cannot be cleared when FaultAlarmLatch is set, unless FaultAlmUnlatch is set and no fault is present.

Mode alarm conditions

The mode alarm reminds an operator that a device has been left in operator control. The mode alarm only turns on when in operator control mode, the program tries to change the state of the device from the operator's commanded state. The alarm does not turn on if an operator places a device in operator mode and changes the state. The D2SD instruction checks for mode alarm conditions, using these rules.

ModeAlarm:	When:
set	$ProgCommand_n \neq ProgCommand_{n-1}$ **and** $ProgCommand_n \neq CommandStatus$
cleared	ProgCommand = CommandStatus **or** the device is in override, hand, or program control mode

Discrete 3-State Device (D3SD)

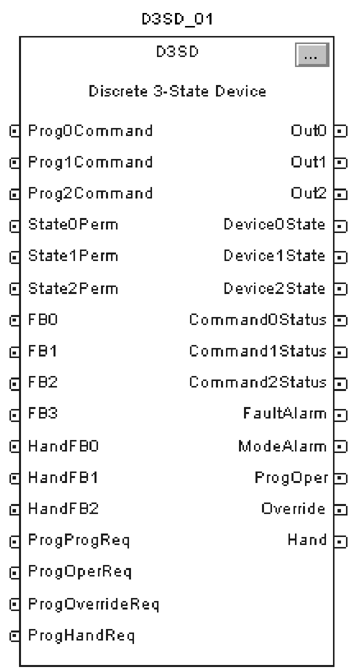
The D3SD instruction controls a discrete device having three possible states such as fast/slow/off, forward/stop/reverse, etc.

Operands:

```
D3SD(D3SD_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
D3SD tag	DISCRETE_3STATE	structure	D3SD structure



Function Block

Operand:	Type:	Format:	Description:
D3SD tag	DISCRETE_3STATE	structure	D2SD structure

DISCRETE_3STATE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
Prog0Command	BOOL	Program state 0 command. This input determines the device state when the device is in Program control. If set, the device is commanded to the 0 state. Default is cleared.
Prog1Command	BOOL	Program state 1 command. This input determines the device state when the device is in Program control. If set, the device is commanded to the 1 state. Default is cleared.
Prog2Command	BOOL	Program state 2 command. This input determines the device state when the device is in Program control. If set, the device is commanded to the 2 state. Default is cleared.

Input Parameter:	Data Type:	Description:
Oper0Req	BOOL	Operator state 0 request. Set by the operator interface to place the device into the 0 state when the device is in Operator control. Default is cleared.
Oper1Req	BOOL	Operator state 1 request. Set by the operator interface to place the device into the 1 state when the device is in Operator control. Default is cleared.
Oper2Req	BOOL	Operator state 2 request. Set by the operator interface to place the device into the 2 state when the device is in Operator control. Default is cleared.
State0Perm	BOOL	State 0 permissive. Unless in Hand or Override mode, this input must be set for the device to enter the 0 state. This input has no effect if the device is already in the 0 state. Default is set.
State1Perm	BOOL	State 1 permissive. Unless in Hand or Override mode, this input must be set for the device to enter the 1 state. This input has no effect if the device is already in the 1 state. Default is set.
State2Perm	BOOL	State 2 permissive. Unless in Hand or Override mode, this input must be set for the device to enter the 2 state. This input has no effect if the device is already in the 2 state. Default is set.
FB0	BOOL	The first feedback input available to the instruction. Default is cleared.
FB1	BOOL	The second feedback input available to the instruction. Default is cleared.
FB2	BOOL	The third feedback input available to the instruction. Default is cleared.
FB3	BOOL	The fourth feedback input available to the instruction. Default is cleared.
HandFB0	BOOL	Hand feedback state 0. This input from a field hand/off/auto station shows the requested state of the field device. Set indicates that the field device is being requested to enter the 0 state; cleared indicates that the field device is being requested to enter some other state. Default is cleared.
HandFB1	BOOL	Hand feedback state 1. This input from a field hand/off/auto station shows the requested state of the field device. Set indicates that the field device is being requested to enter the 1 state; cleared indicates that the field device is being requested to enter some other state. Default is cleared.
HandFB2	BOOL	Hand feedback state 2. This input from a field hand/off/auto station shows the requested state of the field device. Set indicates that the field device is being requested to enter the 2 state; cleared indicates that the field device is being requested to enter some other state. Default is cleared.
FaultTime	REAL	Fault time value. Configure the value in seconds of the time to allow the device to reach a newly commanded state. Set FaultTime = 0 to disable the fault timer. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = any float $\geq$ 0.0 Default = 0.0
FaultAlarmLatch	BOOL	Fault alarm latch input. When set and FaultAlarm is set, latch FaultAlarm. To unlatch FaultAlarm, set FaultAlmUnlatch or clear FaultAlarmLatch. Default is cleared.

Input Parameter:	Data Type:	Description:
FaultAlmUnLatch	BOOL	Fault alarm unlatch input. Set this input when FaultAlarmLatch is set to unlatch FaultAlarm. The instruction clears this input. Default is cleared.
OverrideOnInit	BOOL	Override on initialization request. If this bit is set, then during instruction first scan, the instruction is placed in Operator control with Override set and Hand cleared. If ProgHandReq is set, then Override is cleared and Hand is set. Default is cleared.
OverrideOnFault	BOOL	Override on fault request. Set this value if the device should go to Override mode and enter the OverrideState on a fault alarm. After the fault alarm is removed, the instruction is placed in Operator control. Default is cleared.
Out0State0	BOOL	Output 0 state 0 input. This value determines the value of Output0 when the device is in the 0 state. Default is cleared.
Out0State1	BOOL	Output 0 state 1 input. This value determines the value of Output0 when the device is in the 1 state. Default is cleared.
Out0State2	BOOL	Output 0 state 2 input. This value determines the value of Output0 when the device is in the 2 state. Default is cleared.
Out1State0	BOOL	Output 1 state 0 input. This value determines the value of Output1 when the device is in the 0 state. Default is cleared.
Out1State1	BOOL	Output 1 state 1 input. This value determines the value of Output1 when the device is in the 1 state. Default is cleared.
Out1State2	BOOL	Output 1 state 2 input. This value determines the value of Output1 when the device is in the 2 state. Default is cleared.
Out2State0	BOOL	Output 2 state 0 input. This value determines the value of Output2 when the device is in the 0 state. Default is cleared.
Out2State1	BOOL	Output 2 state 1 input. This value determines the value of Output2 when the device is in the 1 state. Default is cleared.
Out2State2	BOOL	Output 2 state 2 input. This value determines the value of Output2 when the device is in the 2 state. Default is cleared.
OverrideState	DINT	Override state input. Set this input to indicate the state of the device when in Override mode. **Value:** **Indicates:** 2 device should go to the 2 state 1 device should go to the 1 state 0 device should go to the 0 state An invalid value sets the appropriate bit in Status and prevents the instruction from entering the override state. Valid = 0 to 2 Default = 0

Input Parameter:	Data Type:	Description:
FB0State0	BOOL	Feedback 0 state 0 input. This value determines the expected value of FB0 when the device is in the 0 state. Default is cleared.
FB0State1	BOOL	Feedback 0 state 1 input. This value determines the expected value of FB0 when the device is in the 1 state. Default is cleared.
FB0State2	BOOL	Feedback 0 state 2 input. This value determines the expected value of FB0 when the device is in the 2 state. Default is cleared.
FB1State0	BOOL	Feedback 1 state 0 input. This value determines the expected value of FB1 when the device is in the 0 state. Default is cleared.
FB1State1	BOOL	Feedback 1 state 1 input. This value determines the expected value of FB1 when the device is in the 1 state. Default is cleared.
FB1State2	BOOL	Feedback 1 state 2 input. This value determines the expected value of FB1 when the device is in the 2 state. Default is cleared.
FB2State0	BOOL	Feedback 2 state 0 input. This value determines the expected value of FB2 when the device is in the 0 state. Default is cleared.
FB2State1	BOOL	Feedback 2 state 1 input. This value determines the expected value of FB2 when the device is in the 1 state. Default is cleared.
FB2State2	BOOL	Feedback 2 state 2 input. This value determines the expected value of FB2 when the device is in the 2 state. Default is cleared.
FB3State0	BOOL	Feedback 3 state 0 input. This value determines the expected value of FB3 when the device is in the 0 state. Default is cleared.
FB3State1	BOOL	Feedback 3 state 1 input. This value determines the expected value of FB3 when the device is in the 1 state. Default is cleared.
FB3State2	BOOL	Feedback 3 state 2 input. This value determines the expected value of FB3 when the device is in the 2 state. Default is cleared.
ProgProgReq	BOOL	Program program request. Set by the user program to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction in Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set by the user program to request operator control. Holding this set locks the instruction in Operator control. Default is cleared.
ProgOverrideReq	BOOL	Program override request. Set by the user program to request the device to enter Override mode. Ignored if ProgHandReq is set. Default is cleared.
ProgHandReq	BOOL	Program hand request. Set by the user program to request the device to enter Hand mode. Default is cleared.

Input Parameter:	Data Type:	Description:
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input. Default is cleared.
OperOperReq	BOOL	Operator operator request. Set by the operator interface to request Operator control. The instruction clears this input. Default is cleared.
ProgValueReset	BOOL	Reset program control values. When set, all the program request inputs are cleared each execution of the instruction. Default is cleared.

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out0	BOOL	The first output of the instruction.
Out1	BOOL	The second output of the instruction.
Out2	BOOL	The third output of the instruction.
Device0State	BOOL	Device 0 state output. Set when the device is commanded to the 0 state and the feedback indicates the device really is in the 0 state.
Device1State	BOOL	Device 1 state output. Set when the device is commanded to the 1 state and the feedback indicates the device really is in the 1 state.
Device2State	BOOL	Device 2 state output. Set when the device is commanded to the 2 state and the feedback indicates the device really is in the 2 state.
Command0Status	BOOL	Device 0 command status. Set when the device is being commanded to the 0 state; cleared when the device is being commanded to some other state.
Command1Status	BOOL	Device 1 command status. Set when the device is being commanded to the 1 state; cleared when the device is being commanded to some other state.
Command2Status	BOOL	Device 2 command status. Set when the device is being commanded to the 2 state; cleared when the device is being commanded to some other state.
FaultAlarm	BOOL	Fault alarm output. Set if the device has been commanded to a new state, and the FaultTime has expired without the feedback indicating that the new state has actually been reached. Also set if, after reaching a commanded state, the feedbacks suddenly indicate that the device is no longer in the commanded state.
ModeAlarm	BOOL	Mode alarm output. Set if the device is in operator control and a program command changes to a state which is different from the state currently commanded by the operator. This alarm is intended as a reminder that a device was left in Operator control.
ProgOper	BOOL	Program/operator control indicator. Set when in Program control. Cleared when in Operator control.
Override	BOOL	Override mode. Set when the device is in the Override mode.
Hand	BOOL	Hand mode. Set when the device is in the Hand mode.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
FaultTimeInv (Status.1)	BOOL	Invalid FaultTime value. The instruction sets FaultTime = 0.

Output Parameter:	Data Type:	Description:
OverrideStateInv (Status.2)	BOOL	The Override value is out of range
ProgCommandInv (Status.3)	BOOL	Multiple program state command bits are set at the same time.
OperReqInv (Status.4)	BOOL	Multiple operator state request bits are set at the same time.
HandCommandInv (Status.5)	BOOL	Multiple hand state request bits are set at the same time.

Description: The D3SD instruction controls a discrete device having three possible states such as fast/slow/off, forward/stop/reverse, etc. Typical discrete devices of this nature include feeder systems, reversible motors, etc.

Monitoring the D3SD instruction

There is an operator faceplate available for the D3SD instruction. For more information, see appendix Function Block Faceplate Controls.

Arithmetic Status Flags: Arithmetic status flags are not affected.

Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	The fault timer is cleared. ModeAlarm is cleared. All the operator request inputs are cleared. If ProgValueReset is set, all the program request inputs are cleared. When OverrideOnInit is set, ProgOper is cleared (Operator control). If ProgHandReq is cleared and OverrideOnInit is set, clear Hand and set Override (Override mode). If ProgHandReq is set, set Hand and clear Override (Hand mode).	
instruction first run	ProgOper and CommandStatus are cleared.	ProgOper and CommandStatus are cleared.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

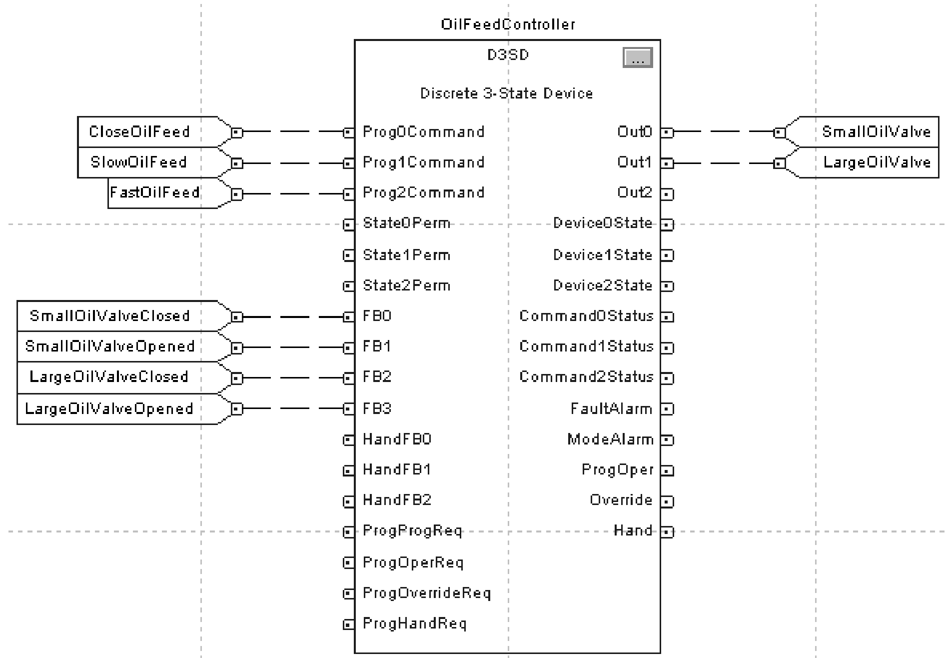
Example: The D3SD instruction is typically used to control 3-state devices such as high/low/off feed systems. In this example, the D3SD instruction controls a feed system consisting of a pair of solenoid valves adding vegetable oil to a batch tank. One of the valves is on a large diameter feed pipe into the batch tank, and the other valve is plumbed in parallel on a small diameter feed pipe. When oil is first added, the D3SD instruction is commanded to the fast feed state (state 2) where both valves are opened. When the oil added approaches the target amount, the D3SD instruction is commanded to the slow feed state (state 1) where the "large valve" is closed and the "small valve" is kept open. When the target is reached, the D3SD instruction is commanded to go to the off state (state 0) and both valves are closed.

As long as the D3SD instruction is in Program control, the valves open according to the CloseOilFeed, SlowOilFeed, and FastOilFeed inputs. The operator can also take Operator control of the feed system if necessary. The solenoid valves in this example have limit switches which indicate when the valves are fully closed or opened. These switches are wired into the FB0, FB1, FB2, and FB3 feedback inputs. This allows the D3SD instruction to generate a *FaultAlarm* if the solenoid valves do not reach their commanded states within the configured *FaultTime*.

Structured Text

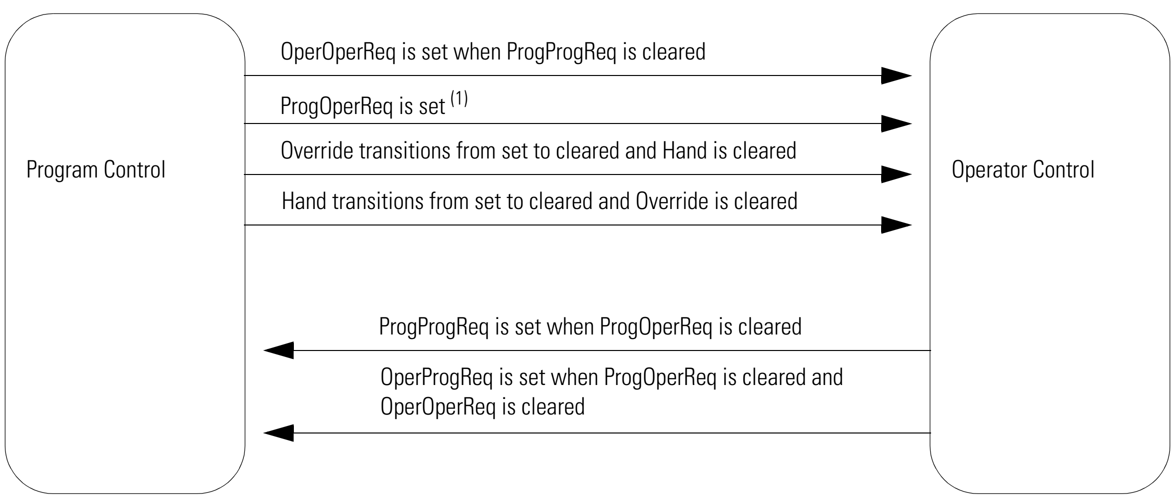
```
OilFeedController.Prog0Command := CloseOilFeed;
OilFeedController.Prog1Command := SlowOilFeed;
OilFeedController.Prog2Command := FastOilFeed;
OilFeedController.FB0 := SmallOilValveClosed;
OilFeedController.FB1 := SmallOilValveOpened;
OilFeedController.FB2 := LargeOilValveClosed;
OilFeedController.FB3 := LargeOilValveOpened;
D3SD(OilFeedController);

SmallOilValve := OilFeedController.Out0;
LargeOilValve := OilFeedController.Out1;
```

Function Block



Switching between Program control and Operator control

The following diagram shows how the D3SD instruction changes between Program control and Operator control.



(1) The instruction remains in Operator control mode when ProgOperReq is set.

For more information on program and operator control, see page B-13.

Commanded state in Program control

The following table describes how the D3SD instruction operates when in Program control.

Prog0 Command:	Prog1 Command:	Prog2 Command:	State0 Perm:	State1 Perm:	State2 Perm:	Description:
cleared	cleared	set	either	either	set	Command0Status is cleared Command1Status is cleared Command2Status is set
cleared	set	cleared	either	set	either	Command0Status is cleared Command1Status is set Command2Status is cleared
set	cleared	cleared	set	either	either	Command0Status is set Command1Status is cleared Command2Status is cleared

If more than one program command input is set:

- the instruction sets the appropriate bit in Status
- if Override and Hand are cleared, the instruction holds the previous state

Commanded state in Operator control

The following table describes how the D3SD instruction operates when in Operator control.

Oper0Req:	Oper1Req:	Oper2Req:	State0 Perm:	State1 Perm:	State2 Perm:	Description:
cleared	cleared	set	either	either	set	Command0Status is cleared Command1Status is cleared Command2Status is set
cleared	set	cleared	either	set	either	Command0Status is cleared Command1Status is set Command2Status is cleared
set	cleared	cleared	set	either	either	Command0Status is set Command1Status is cleared Command2Status is cleared

If more than one operator command input is set:

- the instruction sets the appropriate bit in Status
- if Override and Hand are cleared, the instruction holds the previous state

After every instruction execution, the instruction:

- clears all the operator request inputs
- if ProgValueReset is set, clears all the program request inputs

Hand mode or Override mode

The following table shows how the D3SD instruction determines whether to operate in Hand or Override mode

ProgHandReq:	ProgOverrideReq:	FaultAlarm and OverrideOnFault:	Description:
set	either	either	Hand mode Hand is set Override is cleared
cleared	set	either	Override mode Hand is cleared Override is set
cleared	either	set	Override mode Hand is cleared Override is set

When Override is set, it takes precedence over Program and Operator control. The following table describes how the Override mode affects the commanded state.

Override:	Override State:	Description:
set	2	Command0Status is cleared Command1Status is cleared Command2Status is set
set	1	Command0Status is cleared Command1Status is set Command2Status is cleared
set	0	Command0Status is set Command1Status is cleared Command2Status is cleared

If OverrideState is invalid, the instruction sets the appropriate bit in Status and does not enter the override state.

When Hand is set, it takes precedence over Program and Operator control. The following table describes how the hand mode affects the commanded state.

Hand:	HandFB0:	HandFB1:	HandFB2:	Description:
set	cleared	cleared	set	Command0Status is cleared Command1Status is cleared Command2Status is set
set	cleared	set	cleared	Command0Status is cleared Command1Status is set Command2Status is cleared
set	set	cleared	cleared	Command0Status is set Command1Status is cleared Command2Status is cleared

If more than one HandFB input is set, the instruction sets the appropriate bit in Status and, if Hand is set, the instruction holds the previous state.

Output state

The D3SD output state is based on the state of the command status.

CommandStatus:	Output state:
Command0Status is set	Out0 = Out0State0 Out1 = Out1State0 Out2 = Out2State0
Command0Status is set **and** FB0 = FB0State0 **and** FB1 = FB1State0 **and** FB2 = FB2State0 **and** FB3 = FB3State0	stop and clear the fault timer Device0State is set
Command1Status is set	Out0 = Out0State1 Out1 = Out1State1 Out2 = Out2State1
Command1Status is set **and** FB0 = FB0State1 **and** FB1 = FB1State1 **and** FB2 = FB2State1 **and** FB3 = FB3State1	stop and clear the fault timer, Device1State is set
Command2Status is set	Out0 = Out0State2 Out1 = Out1State2 Out2 = Out2State2
Command2Status is set **and** FB0 = FB0State2 **and** FB1 = FB1State2 **and** FB2 = FB2State2 **and** FB3 = FB3State2	stop and clear the fault timer Device2State is set

Fault alarm conditions

The D3SD instruction checks for these fault alarm conditions.

Fault alarm condition resulting from:	Rules:
device state was commanded to change, but the feedback did not indicate that the desired state was actually reached within the FaultTime.	Start the fault timer when $Command0Status_n \neq Command0Status_{n-1}$ or $Command1Status_n \neq Command1Status_{n-1}$ or $Command2Status_n \neq Command2Status_{n-1}$ Set FaultAlarm when the fault timer done and FaultTime > 0.0
the device unexpectedly leaving a state (according to the feedback) without being commanded to.	Set FaultAlarm when fault timer is not timing and one of the following conditions is satisfied: Command0Status is set and Device0State is cleared Command1Status is set and Device1State is cleared Command2Status is set and Device2State is cleared

If there is no fault present, FaultAlarm is cleared if one of the following conditions is met:

- Command0Status is set and Device0State is set
- Command1Status is set and Device1State is set
- Command2Status is set and Device2State is set
- FaultTime ≤ 0

FaultAlarm cannot be cleared when FaultAlarmLatch is set, unless FaultAlmUnlatch is set and no fault is present.

Mode alarm conditions

The mode alarm reminds an operator that a device has been left in Operator control. The mode alarm only turns on when in Operator control, the program tries to change the state of the device from the operator's commanded state. The alarm does not turn on if an operator places a device in Operator control and changes the mode. The D3SD instruction checks for mode alarm conditions, using these rules.

ModeAlarm:	When:
set	Prog2Command ≠ $\text{Prog2Command}_{n-1}$ **and** Prog2Command ≠ Command2Status **or** Prog1Command ≠ $\text{Prog1Command}_{n-1}$ **and** Prog1Command ≠ Command1Status **or** Prog0Command ≠ $\text{Prog0Command}_{n-1}$ **and** Prog0Command ≠ Command0Status
cleared	Prog2Command = Command2Status **and** Prog1Command = Command1Status **and** Prog0Command = Command0Status **or** the device is in override, hand, or program control mode

Deadtime (DEDT)

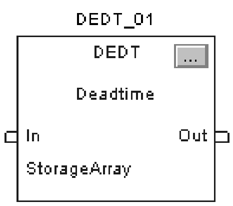
The DEDT instruction performs a delay of a single input. You select the amount of deadtime delay.

Operands:

```
DEDT(DEDT_tag,storage);
```

Structured Text

Operand:	Type:	Format:	Description:
DEDT tag	DEADTIME	structure	DEDT structure
storage	REAL	array	deadtime buffer



Function Block

Operand:	Type:	Format:	Description:
DEDT tag	DEADTIME	structure	DEDT structure
storage	REAL	array	deadtime buffer

DEADTIME Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
InFault	BOOL	Bad health indicator for the input. If the input value is read from an analog input, then InFault is controlled by fault status on the analog input. If set, InFault indicates that the input signal has an error, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Out is held. Default is cleared. Cleared = good health
Deadtime	REAL	Deadtime input to the instruction. Enter the deadtime in seconds. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = 0.0 to (StorageArray size * DeltaT) Default = 0.0
Gain	REAL	Gain input to the instruction. The value of In is multiplied by this value. This allows simulation of a process gain. Valid = any float Default = 1.0
Bias	REAL	Bias input to the instruction. The value of In multiplied by the Gain is added to this value. This allows simulation of an ambient condition. Valid = any float Default = 0.0

Input Parameter:	Data Type:	Description:
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode Valid = 0 to 2 Default = 0 For more information about timing modes, see appendix Function Block Attributes.
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the deadtime algorithm. Arithmetic status flags are set for this output.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
InFaulted (Status.1)	BOOL	In health is bad.
DeadtimeInv (Status.2)	BOOL	Invalid Deadtime value.
TimingMode (Status.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Description: The DEDT instruction uses a data buffer to store delayed data, thereby allowing any length deadtime desired. The DEDT instruction is designed to execute in a task where the scan rate remains constant.

To use the DEDT instruction, create a storage array to store the deadtime buffer to hold the samples of (In x Gain) + Bias. The storage array should be large enough to hold the largest desired deadtime, using this formula:

StorageArray Size Needed = Maximum Deadtime (secs) / DeltaT (secs)

Servicing the deadtime buffer

During runtime, the instruction checks for a valid Deadtime. Deadtime must be between 0.0 and (StorageArray Size x DeltaT).

If the Deadtime is invalid, the instruction sets an appropriate Status bit and sets Out = (In x Gain) + Bias.

The deadtime buffer functions as a first-in, first-out buffer. Every time the deadtime algorithm executes, the oldest value in the deadtime buffer is moved into Out. The remaining values in the buffer shift downward and the value ((In x Gain) + Bias) is moved to the beginning of the deadtime buffer. A new value that is placed in the deadtime buffer appears in the Out after Deadtime seconds.

The number of array elements required to perform the programmed delay is calculated by dividing Deadtime by DeltaT. If Deadtime is not evenly divisible by DeltaT, then the number of array elements and the programmed delay are rounded to the nearest increment of DeltaT. For example, to find the number of array elements required to perform the programmed delay given Deadtime = 4.25s and DeltaT = 0.50s:

4.25s / 0.50s = 8.5
rounds up to 9 array elements required

The actual delay applied to the input in this example is:

number of array elements x DeltaT = programmed delay or
9 x 0.5s = 4.5s

Runtime changes to either Deadtime or DeltaT change the point in which values are moved out of the buffer. The number of elements required to perform the programmed delay can either increase or decrease. Prior to servicing the deadtime buffer, the following updates occur:

- If the number of required elements needs to increase, the new buffer elements are populated with the oldest value in the current deadtime buffer.
- If the number of required elements needs to decrease, the oldest elements of the current deadtime buffer are discarded.

Instruction behavior on InFault transition.

When InFault is set (bad), the instruction suspends execution, holds the last output, and sets the appropriate bit in Status.

When InFault transitions from set to cleared, the instruction sets Out and all values in the deadtime buffer equal to In x Gain + Bias.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

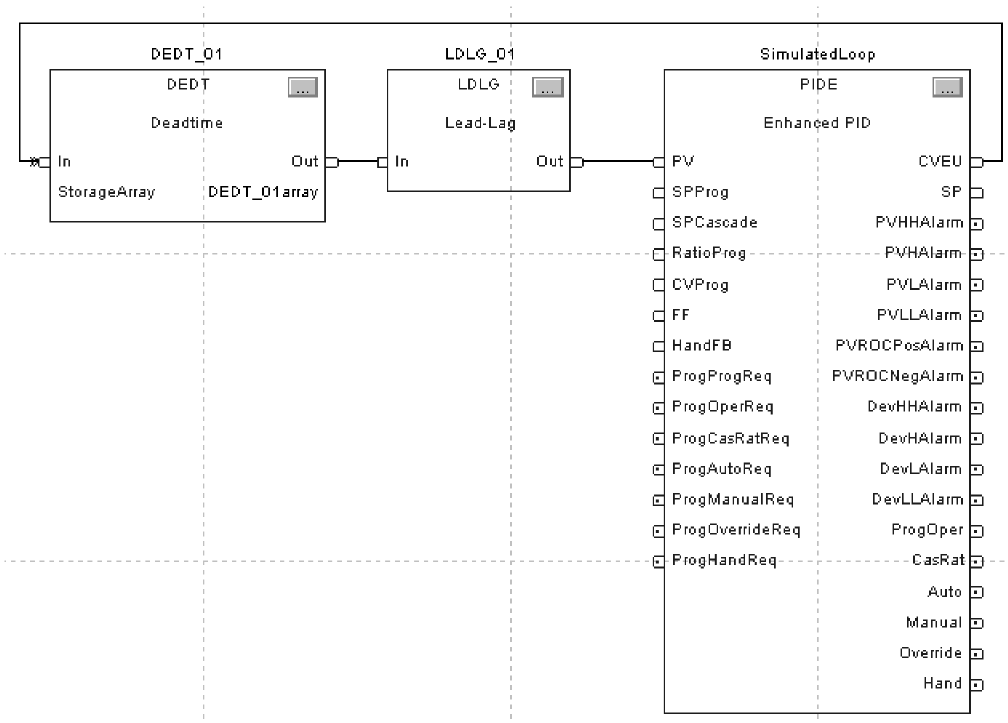
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	If InFault is cleared, Out and all values in the deadtime buffer are set equal to (In x Gain + Bias).	
instruction first run	If InFault is cleared, Out and all values in the deadtime buffer are set equal to (In x Gain + Bias).	
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: In this example, the DEDT instruction simulates a deadtime delay in a simulated process. The output of the PIDE instruction is passed through a deadtime delay and a first-order lag to simulate the process. The array DEDT_01array is a REAL array with 100 elements to support a deadtime of up to 100 samples. For example, if this routine executes every 100 msec, the array would support a deadtime of up to 10 seconds.

Structured Text

```
DEDT_01.In := SimulatedLoop.CVEU;
DEDT(DEDT_01,DEDT_01array);

LDLG_01.In := DEDT_01.Out;
LDLG(LDLG_01);

SimulatedLoop.PV := LDLG_01.Out;
PIDE(SimulatedLoop);
```

Function Block



Function Generator (FGEN)

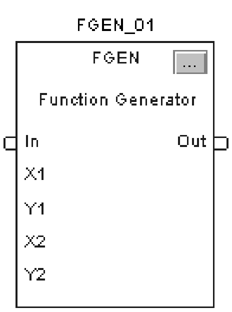
The FGEN instruction converts an input based on a piece-wise linear function.

Operands:

```
FGEN(FGEN_tag,X1,Y1,X2,Y2);
```

Structured Text

Operand:	Type:	Format:	Description:
FGEN tag	FUNCTION_ GENERATOR	structure	FGEN structure
X1	REAL	array	X-axis array, table one. Combine with the Y-axis array, table one to define the points of the first piece-wise linear curve. valid = any float
Y1	REAL	array	Y-axis array, table one. Combine with the X-axis array, table one to define the points of the first piece-wise linear curve. valid = any float
X2	REAL	array	(optional) X-axis array, table two. Combine with the Y-axis array, table two to define the points of the second piece-wise linear curve. valid = any float
Y2	REAL	array	(optional) Y-axis array, table two. Combine with the X-axis array, table two to define the points of the second piece-wise linear curve. valid = any float



Function Block

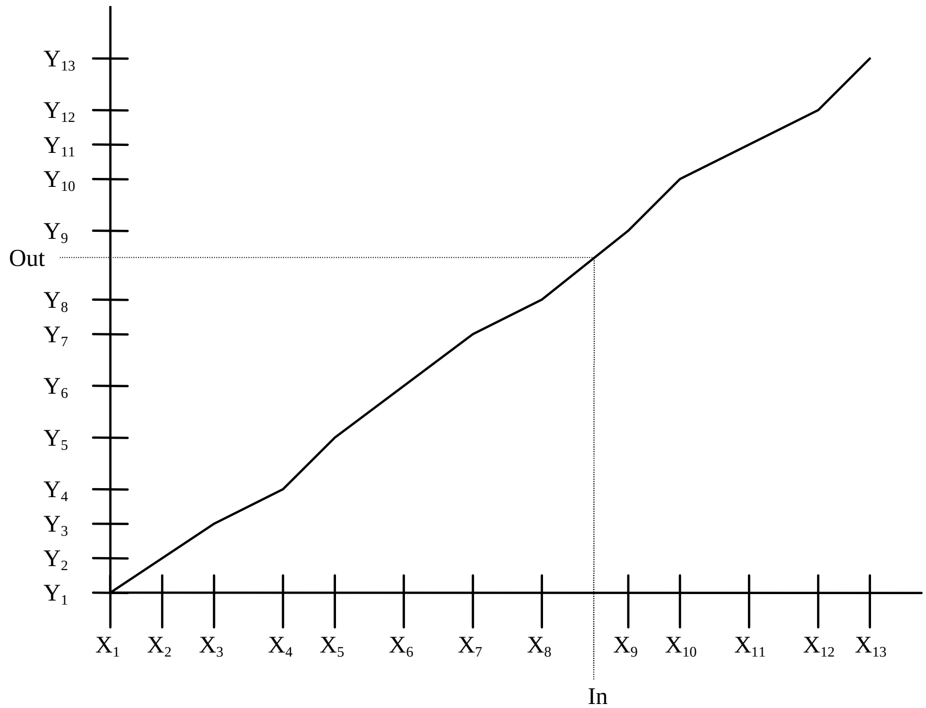
The operands are the same as for the structured text FGEN instruction.

FUNCTION_GENERATOR Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
XY1Size	DINT	Number of points in the piece-wise linear curve to use from table one. If the value is less than one and Select is cleared, the instruction sets the appropriate bit in Status and the output is not changed. Valid = 1 to (smallest of X1 and Y1 array sizes) Default = 1
XY2Size	DINT	Number of points in the piece-wise linear curve to use from table two. If the value is less than one and Select is set, the instruction sets the appropriate bit in Status and the output is not changed. Valid = 0 to (smallest of X2 and Y2 array sizes) Default = 0
Select	BOOL	This input determines which table to use. When cleared, the instruction uses table one. When set, the instruction uses table two. Default is cleared.

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	Output of the instruction. Arithmetic status flags are set for this output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	Instruction generated a fault.
XY1SizeInv (Status.1)	BOOL	Size of table 1 is invalid or not compatible with the array size.
XY2SizeInv (Status.2)	BOOL	Size of table 2 is invalid or not compatible with the array size.
XisOutofOrder (Status.3)	BOOL	The X parameters are not sorted.

Description: The following illustration shows how the FGEN instruction converts a twelve-segment curve:



The X-axis parameters must follow the relationship:

X[1] < X[2] < X[3] < ... < X[XY<n>Size],

where XY<n>Size > 1 and is a number of points in the piece-wise linear curve and where n is 1 or 2 for the table selected. You must create sorted X-axis elements in the X arrays.

The Select input determines which table to use for the instruction. When the instruction is executing on one table, you can modify the values in the other table. Change the state of Select to execute with the other table.

Before calculating Out, the X axis parameters are scanned. If they are not sorted in ascending order, the appropriate bit in Status is set and Out remains unchanged. Also, if XY1Size or XY2Size is invalid, the instruction sets the appropriate bit in Status and leaves Out unchanged.

The instruction uses this algorithm to calculate Out based on In:

- When In ≤ X[1], set Out = Y[1]
- When In > X[XY<n>Size], set Out = Y[XY<n>Size]
- When X[n] < In ≤ X[n+1], calculate Out = ((Y[n+1]-Yn)/(X[n+1]-Xn))*(In-Xn)+Yn

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

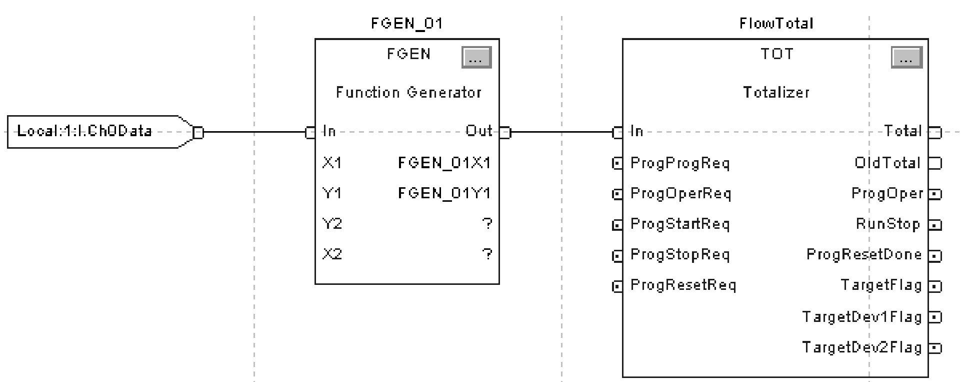
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The FGEN instruction characterizes a flow signal which is then totalized using a TOT instruction. The FGEN_01X1 and FGEN_01Y1 arrays are REAL arrays of 10 elements each to support up to a 9 segment curve. You can use arrays of any size to support a curve of any desired number of segments.

Structured Text

```
FGEN_01.IN := Local:1:I.Ch0Data;
FGEN(FGEN_01,FGEN_01X1,FGEN_01Y1);

FlowTotal.In := FGEN_01.Out;
TOT(FlowTotal);
```

Function Block



Lead-Lag (LDLG)

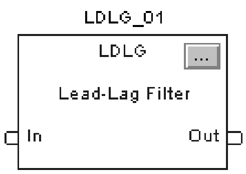
The LDLG instruction provides a phase lead-lag compensation for an input signal. This instruction is typically used for feedforward PID control or for process simulations.

Operands:

```
LDLG(LDLG_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
LDLG tag	LEAD_LAG	structure	LDLG structure



Function Block

Operand:	Type:	Format:	Description:
LDLG tag	LEAD_LAG	structure	LDLG structure

LEAD_LAG Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	Request to initialize filter control algorithm. When Initialize is set, Out = (In x Gain) + Bias. Default = cleared.
Lead	REAL	The lead time in seconds. Set Lead = 0.0 to disable the lead control algorithm. If Lead < 0.0, the instruction sets the appropriate bit in Status and limits Lead to 0.0. If Lead > maximum positive float, the instruction sets the appropriate bit in Status. Valid = any float ≥ 0.0 Default = 0.0
Lag	REAL	The lag time in seconds. The minimum lag time is DeltaT/2. If Lag < DeltaT/2, the instruction sets the appropriate bit in Status and limits Lag to DeltaT/2. If Lag > maximum positive float, the instruction sets the appropriate bit in Status. Valid = any float ≥ DeltaT/2 Default = 0.0
Gain	REAL	The process gain multiplier. This value allows the simulation of a process gain. The In signal is multiplied by this value. I = (In x Gain) + Bias Valid = any float Default = 1.0

Input Parameter:	Data Type:	Description:
Bias	REAL	The process offset level. This value allows the simulation of an ambient condition. This value is summed with the results of the multiplication of In times Gain. I = (In x Gain) + Bias Valid = any float Default = 0.0
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode Valid = 0 to 2 Default = 0 For more information about timing modes, see appendix Function Block Attributes.
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are used for this output.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
LeadInv (Status.1)	BOOL	Lead < minimum value or Lead > maximum value.
LagInv (Status.2)	BOOL	Lag < minimum value or Lag > maximum value.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Description: The LDLG instruction supports one lead and lag in series. The instruction also allows configurable gain and bias factors. The LDLG instruction is designed to execute in a task where the scan rate remains constant.

The LDLG instruction uses this equation:

$$H(s) = \left[\frac{1 + Lead \times s}{1 + Lag \times s}\right]$$

with these parameters limits:

Parameter:	Limitations:
Lead	LowLimit = 0.0 HighLimit = maximum positive float
Lag	LowLimit = DeltaT/2 (DeltaT is in seconds) HighLimit = maximum positive float

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. When the value computed for the output becomes valid, the instruction initializes the internal parameters and sets Out = (In x Gain) + Bias.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

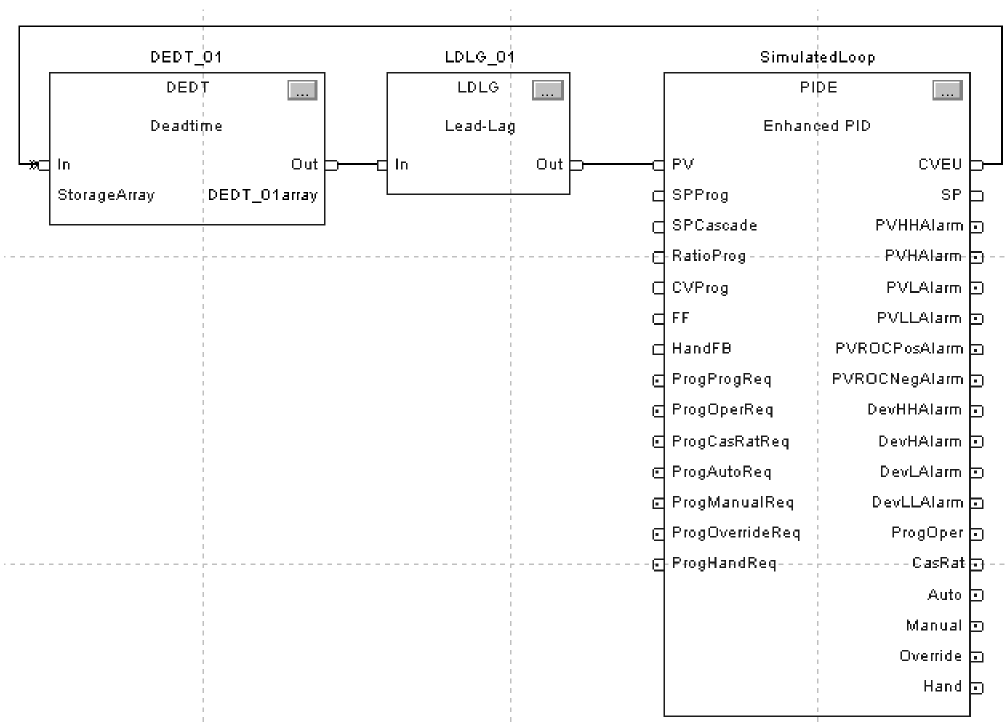
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	The instruction sets Out = (In x Gain) + Bias. The control algorithm is not executed.	
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The LDLG instruction in this example adds a first-order lag to a simulated process. Optionally, you could enter a Gain on the LDLG instruction to simulate a process gain and you could enter a Bias to simulate an ambient condition.

Structured Text

```
DEDT_01.In := SimulatedLoop.CVEU;
DEDT(DEDT_01,DEDT_01array);

LDLG_01.In := DEDT_01.Out;
LDLG(LDLG_01);

SimulatedLoop.PV := LDLG_01.Out;
PIDE(SimulatedLoop);
```

Function Block



Enhanced PID (PIDE)

The PIDE instruction provides enhanced capabilities over the standard PID instruction. The instruction uses the velocity form of the PID algorithm. The gain terms are applied to the change in the value of error or PV, not the value of error or PV.

Operands:

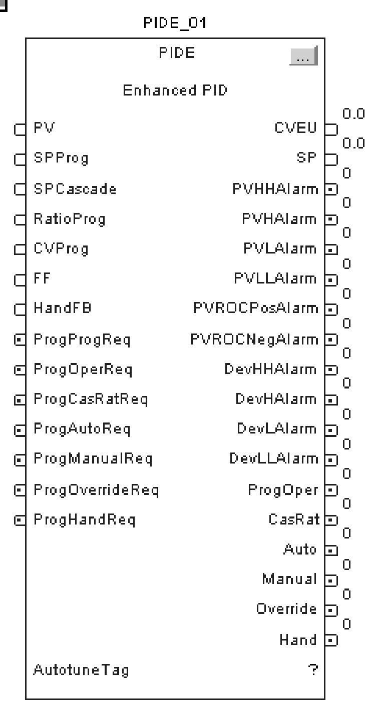
```
PIDE(PIDE_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
PIDE tag	PIDE_ENHANCED	structure	PIDE structure

Structured text does not support the autotune tag that is available in function block.

Function Block



Operand:	Type:	Format:	Description:
PIDE tag	PIDE_ENHANCED	structure	PIDE structure
autotune tag	PIDE_AUTOTUNE	structure	(optional) autotune structure, see page 11-56

PID_ENHANCED Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
PV	REAL	Scaled process variable input. This value is typically read from an analog input module. Valid = any float Default = 0.0
PVFault	BOOL	PV bad health indicator. If PV is read from an analog input, then PVFault is normally controlled by the analog input fault status. When PVFault is set, it indicates that the input signal has an error. Default is cleared = "good health"
PVEUMax	REAL	Maximum scaled value for PV. The value of PV and SP which corresponds to 100 percent span of the Process Variable. Valid = PVEUMin < PVEUMax ≤ maximum positive float Default = 100.0
PVEUMin	REAL	Minimum scaled value for PV. The value of PV and SP which corresponds to 0 percent span of the Process Variable. Valid = maximum negative float ≤ PVEUMin < PVEUMax Default = 0.0
SPProg	REAL	SP program value, scaled in PV units. SP is set to this value when in Program control and not Cascade/Ratio mode. If the value of SPProg < SPLLimit or > SPHLimit, the instruction sets the appropriate bit in Status and limits the value used for SP. Valid = SPLLimit to SPHLimit Default = 0.0
SPOper	REAL	SP operator value, scaled in PV units. SP is set to this value when in Operator control and not Cascade/Ratio mode. If the value of SPOper < SPLLimit or > SPHLimit, the instruction sets the appropriate bit in Status and limits the value used for SP. Valid = SPLLimit to SPHLimit Default = 0.0
SPCascade	REAL	SP Cascade value, scaled in PV units. If CascadeRatio is set and UseRatio is cleared, then SP = SPCascade. This is typically the CVEU of a primary loop. If CascadeRatio and UseRatio are set, then SP = (SPCascade x Ratio). If the value of SPCascade < SPLLimit or > SPHLimit, set the appropriate bit in Status and limit the value used for SP. Valid = SPLLimit to SPHLimit Default = 0.0
SPHLimit	REAL	SP high limit value, scaled in PV units. If SPHLimit > PVEUMax, the instruction sets the appropriate bit in Status. Valid = SPLLimit to PVEUMax Default = 100.0
SPLLimit	REAL	SP low limit value, scaled in PV units. If SPLLimit < PVEUMin, the instruction sets the appropriate bit in Status. If SPHLimit < SPLLimit, the instruction sets the appropriate bit in Status and limits SP using the value of SPLLimit. Valid = PVEUMin to SPHLimit Default = 0.0
UseRatio	BOOL	Allow ratio control permissive. Set to enable ratio control when in Cascade/Ratio mode. Default is cleared.

Input Parameter:	Data Type:	Description:
RatioProg	REAL	Ratio program multiplier. Ratio and RatioOper are set equal to this value when in Program control. If RatioProg < RatioLLimit or > RatioHLimit, the instruction sets the appropriate bit in Status and limits the value used for Ratio. Valid = RatioLLimit to RatioHLimit Default = 1.0
RatioOper	REAL	Ratio operator multiplier. Ratio is set equal to this value when in Operator control. If RatioOper < RatioLLimit or > RatioHLimit, the instruction sets the appropriate bit in Status and limits the value used for Ratio. Valid = RatioLLimit to RatioHLimit Default = 1.0
RatioHLimit	REAL	Ratio high limit value. Limits the value of Ratio obtained from RatioProg or RatioOper. If RatioHLimit < RatioLLimit, the instruction sets the appropriate bit in Status and limits Ratio using the value of RatioLLimit. Valid = RatioLLimit to maximum positive float Default = 1.0
RatioLLimit	REAL	Ratio low limit value. Limits the value of Ratio obtained from RatioProg or RatioOper. If RatioLLimit < 0, the instruction sets the appropriate bit in Status and limits the value to zero. If RatioHLimit < RatioLLimit, the instruction sets the appropriate bit in Status and limits Ratio using the value of RatioLLimit. Valid = 0.0 to RatioHLimit Default = 1.0
CVFault	BOOL	Control variable bad health indicator. If CVEU controls an analog output, then CVFault normally comes from the analog output's fault status. When set, CVFault indicates an error on the output module and the instruction sets the appropriate bit in Status. Default is cleared = "good health"
CVInitReq	BOOL	CV initialization request. This signal is normally controlled by the "In Hold" status on the analog output module controlled by CVEU or from the InitPrimary output of a secondary PID loop. Default is cleared.
CVInitValue	REAL	CVEU initialization value, scaled in CVEU units. When CVInitializing is set, CVEU = CVInitValue and CV equals the corresponding percentage value. CVInitValue comes from the feedback of the analog output controlled by CVEU or from the setpoint of a secondary loop. Instruction initialization is disabled when CVFaulted or CVEUSpanInv is set. Valid = any float Default = 0.0
CVProg	REAL	CV program manual value. CV equals this value when in Program Manual mode. If CVProg < 0 or > 100, or < CVLLimit or > CVHLimit when CVManLimiting is set, the instruction sets the appropriate bit in Status and limits the CV value. Valid = 0.0 to 100.0 Default = 0.0
CVOper	REAL	CV operator manual value. CV equals this value when in Operator Manual mode. If not Operator Manual mode, the instruction sets CVOper = CV at the end of each instruction execution. If CVOper < 0 or > 100, or < CVLLimit or > CVHLimit when CVManLimiting is set, the instruction sets the appropriate bit in Status and limits the CV value. Valid = 0.0 to 100.0 Default = 0.0
CVOverride	REAL	CV override value. CV equals this value when in override mode. This value should correspond to a safe state output of the PID loop. If CVOverride < 0 or >100, the instruction sets the appropriate bit in Status and limits the CV value. Valid = 0.0 to 100.0 Default = 0.0

Input Parameter:	Data Type:	Description:
CVPrevious	REAL	CV_{n-1} value. If CVSetPrevious is set, CV_{n-1} equals this value. CV_{n-1} is the value of CV from the previous execution. CVPrevious is ignored when in manual, override or hand mode or when CVInitializing is set. If CVPrevious < 0 or > 100, or < CVLLimit or > CVHLimit when in Auto or cascade/ratio mode, the instruction sets the appropriate bit in Status and limits the CV_{n-1} value. Valid = 0.0 to 100.0 Default = 0.0
CVSetPrevious	BOOL	Request to use CVPrevious. If set, CV_{n-1} = CVPrevious. Default is cleared.
CVManLimiting	BOOL	Limit CV in manual mode request. If Manual mode and CVManLimiting is set, CV is limited by the CVHLimit and CVLLimit values. Default is cleared.
CVEUMax	REAL	Maximum value for CVEU. The value of CVEU which corresponds to 100 percent CV. If CVEUMax = CVEUMin, the instruction sets the appropriate bit in Status. Valid = any float Default = 100.0
CVEUMin	REAL	Minimum value of CVEU. The value of CVEU which corresponds to 0 percent CV. If CVEUMax = CVEUMin, the instruction sets the appropriate bit in Status. Valid = any float Default = 0.0
CVHLimit	REAL	CV high limit value. This is used to set the CVHAlarm output. It is also used for limiting CV when in Auto or Cascade/Ratio mode, or Manual mode if CVManLimiting is set. If CVHLimit > 100 or < CVLLimit, the instruction sets the appropriate bit in Status. If CVHLimit < CVLLimit, the instruction limits CV using the value of CVLLimit. Valid = CVLLimit < CVHLimit ≤ 100.0 Default = 100.0
CVLLimit	REAL	CV low limit value. This is used to set the CVLAlarm output. It is also used for limiting CV when in Auto or Cascade/Ratio mode, or Manual mode if CVManLimiting is set. If CVLLimit < 0 or CVHLimit < CVLLimit, the instruction sets the appropriate bit in Status. If CVHLimit < CVLLimit, the instruction limits CV using the value of CVLLimit. Valid = 0.0 ≤ CVLLimit < CVHLimit Default = 0.0
CVROCLimit	REAL	CV rate of change limit, in percent per second. Rate of change limiting is only used when in Auto or Cascade/Ratio modes or Manual mode if CVManLimiting is set. Enter 0 to disable CV ROC limiting. If CVROCLimit < 0, the instruction sets the appropriate bit in Status and disables CV ROC limiting. Valid = 0.0 to maximum positive float Default = 0.0
FF	REAL	Feed forward value. The value of feed forward is summed with CV after the zero-crossing deadband limiting has been applied to CV. Therefore changes in FF are always reflected in the final output value of CV. If FF < –100 or > 100, the instruction sets the appropriate bit in Status and limits the value used for FF. Valid = -100.0 to 100.0 Default = 0.0
FFPrevious	REAL	FF_{n-1} value. If FFSetPrevious is set, the instruction sets FF_{n-1} = FFPrevious. FF_{n-1} is the value of FF from the previous execution. If FFPrevious < –100 or > 100, the instruction sets the appropriate bit in Status and limits value used for FF_{n-1}. Valid = -100.0 to 100.0 Default = 0.0

Input Parameter:	Data Type:	Description:
FFSetPrevious	BOOL	Request to use FFPrevious. If set, FF_{n-1} = FFPrevious. Default is cleared.
HandFB	REAL	CV Hand feedback value. CV equals this value when in Hand mode and HandFBFault is cleared (good health). This value typically comes from the output of a field mounted hand/auto station and is used to generate a bumpless transfer out of hand mode. If HandFB < 0 or > 100, the instruction sets the appropriate bit in Status and limits the value used for CV. Valid = 0.0 to 100.0 Default = 0.0
HandFBFault	BOOL	HandFB value bad health indicator. If the HandFB value is read from an analog input, then HandFBFault is typically controlled by the status of the analog input channel. When set, HandFBFault indicates an error on the input module and the instruction sets the appropriate bit in Status. Default is cleared = "good health"
WindupHIn	BOOL	Windup high request. When set, the CV cannot integrate in a positive direction. This signal is typically obtained from the WindupHOut output from a secondary loop. Default is cleared.
WindupLIn	BOOL	Windup low request. When set, the CV cannot integrate in a negative direction. This signal is typically obtained from the WindupLOut output from a secondary loop. Default is cleared.
ControlAction	BOOL	Control action request. Set to calculate error as E = PV - SP; clear to calculate error as E = SP - PV. Default is cleared.
DependIndepend	BOOL	Dependent/independent control request. When set, use the dependent form of the PID equation; when cleared, use the independent form of the equations. Default is cleared.
PGain	REAL	Proportional gain. When the independent form of the PID algorithm is selected, enter the unitless proportional gain into this value. When the dependent PID algorithm is selected, enter the unitless controller gain into this value. Enter 0 to disable the proportional control. If PGain < 0, the instruction sets the appropriate bit in Status and uses of value of PGain = 0. Valid = 0.0 to maximum positive float Default = 0.0
IGain	REAL	Integral gain. When the independent form of the PID algorithm is selected, enter the integral gain in units of 1/minutes into this value. When the dependent PID algorithm is selected, enter the integral time constant in units of minutes/repeat into this value. Enter 0 to disable the integral control. If IGain < 0, the instruction sets the appropriate bit in Status and uses a Value of IGain = 0. Valid = 0.0 to maximum positive float Default = 0.0
DGain	REAL	Derivative gain. When the independent form of the PID algorithm is selected, enter the derivative gain in units of minutes into this value. When the dependent PID algorithm is used, enter the derivative time constant in units of minutes into this value. Enter 0 to disable the derivative control. If DGain < 0, the instruction sets the appropriate bit in Status and uses a value of DGain = 0. Valid = 0.0 to maximum positive float Default = 0.0
PVEProportional	BOOL	Proportional PV control request. When set, calculate the proportional term (DeltaPTerm) using the change in process variable (PVPercent). When cleared, use the change in error (EPercent). Default is cleared.

Input Parameter:	Data Type:	Description:
PVEDerivative	BOOL	Derivative PV control request. When set, calculate the derivative term (DeltaDTerm) using the change in process variable (PVPercent). When cleared, use the change in error (EPercent). Default is set.
DSmoothing	BOOL	Derivative Smoothing request. When set, changes in the derivative term are smoothed. Derivative smoothing causes less output "jitters" as a result of a noisy PV signal but also limits the effectiveness of high derivative gains. Default is cleared.
PVTracking	BOOL	SP track PV request. Set to cause SP to track PV when in manual mode. Ignored when in Cascade/Ratio or Auto mode. Default is cleared.
ZCDeadband	REAL	Zero crossing deadband range, scaled in PV units. Defines the zero crossing deadband range. Enter 0 to disable the zero crossing deadband checking. If ZCDeadband < 0, the instruction sets the appropriate bit in Status and disables zero crossing deadband checking. Valid = 0.0 to maximum positive float Default = 0.0
ZCOff	BOOL	Zero crossing disable request. Set to disable zero crossing for the deadband calculation. Default is cleared.
PVHHLimit	REAL	PV high-high alarm limit value, scaled in PV units. Valid = any float Default = maximum positive float
PVHLimit	REAL	PV high alarm limit value, scaled in PV units. Valid = any float Default = maximum positive float
PVLLimit	REAL	PV low alarm limit value, scaled in PV units. Valid = any float Default = maximum negative float
PVLLLimit	REAL	PV low-low alarm limit value, scaled in PV units. Valid = any float Default = maximum negative float
PVDeadband	REAL	PV alarm limit deadband value, scaled in PV units. Deadband is the delta value between the turn-on and turn-off value for each of the PV alarm limits. If PVDeadband < 0.0, the instruction sets the appropriate bit in Status and limits PVDeadband to zero. Valid = 0.0 to maximum positive float Default = 0.0
PVROCPosLimit	REAL	PV positive rate of change alarm limit. The limit value for a positive (increasing) change in PV, scaled in PV units per seconds. Enter 0.0 to disable positive PVROC alarm checking. If PVROCPosLimit < 0.0, the instruction sets the appropriate bit in Status and disables PVROC checking. Valid = 0.0 to maximum positive float Default = 0.0 PV/second
PVROCNegLimit	REAL	PV negative rate of change alarm limit. The limit value for a negative (decreasing) change in PV, scaled in PV units per seconds. Enter 0.0 to disable negative PVROC alarm checking. If PVROCNegLimit < 0, the instruction sets the appropriate bit in Status and disables negative PVROC checking. Valid = 0.0 to maximum positive float Default = 0.0

Input Parameter:	Data Type:	Description:
PVROCPeriod	REAL	PV rate of change sample period. The time period, in seconds, over which the rate of change for PV is evaluated. Enter 0 to disable PVROC alarm checking. If PVROCPeriod < 0.0, the instruction sets the appropriate bit in Status, and disables positive and negative PVROC checking. Valid = any float ≥ 0.0 Default = 0.0 seconds
DevHHLimit	REAL	Deviation high-high alarm limit value, scaled in PV units. Deviation is the difference in value between the process variable (PV) and the setpoint (SP). Deviation alarming alerts the operator to a discrepancy between the process variable and the setpoint value. If DevHHLimit < 0.0, the instruction sets the appropriate bits in Status and sets DevHHLimit = 0.0. Valid = 0.0 to maximum positive float Default = maximum positive float
DevHLimit	REAL	Deviation high alarm limit value, scaled in PV units. Deviation is the difference in value between the process variable (PV) and the setpoint (SP). Deviation alarming alerts the operator to a discrepancy between the process variable and the setpoint value. If DevHLimit < 0.0, the instruction sets the appropriate bit in Status and sets DevHLimit = 0.0. Valid = 0.0 to maximum positive float Default = maximum positive float
DevLLimit	REAL	Deviation low alarm limit value, scaled in PV units. Deviation is the difference in value between the process variable (PV) and the setpoint (SP). Deviation alarming alerts the operator to a discrepancy between the process variable and the setpoint value. If DevLLimit < 0.0, the instruction sets the appropriate bit in Status and sets DevLLimit = 0.0. Valid = 0.0 to maximum positive float Default = maximum positive float
DevLLLimit	REAL	Deviation low-low alarm limit value, scaled in PV units. Deviation is the difference in value between the process variable (PV) and the setpoint (SP). Deviation alarming alerts the operator to a discrepancy between the process variable and the setpoint value. If DevLLLimit < 0.0, the instruction sets the appropriate bit in Status and sets DevLLLimit = 0.0. Valid = 0.0 to maximum positive float Default = maximum positive float
DevDeadband	REAL	The deadband value for the Deviation alarm limits, scaled in PV units. Deadband is the delta value between the turn-on and turn-off value for each of the Deviation alarm limits. If DevDeadband < 0.0, the instruction sets the appropriate bit in Status and sets DevDeadband = 0.0. Valid = 0.0 to maximum positive float Default = 0.0
AllowCasRat	BOOL	Allow cascade/ratio mode permissive. Set to allow Cascade/Ratio mode to be selected using either ProgCascadeRatioReq or OperCascadeRatioReq. Default is cleared.
ManualAfterInit	BOOL	Manual mode after initialization request. When set, the instruction is placed in Manual mode when CVInitializing is set, unless the current mode is Override or Hand. When ManualAfterInit is cleared, the instruction's mode is not changed, unless requested to do so. Default is cleared.
ProgProgReq	BOOL	Program program request. Set by the user program to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction in Program control. When ProgValueReset is set, the instruction clears the input each execution. Default is cleared.

Input Parameter:	Data Type:	Description:
ProgOperReq	BOOL	Program operator request. Set by the user program to request Operator control. Holding this set locks the instruction in Operator control. When ProgValueReset is set, the instruction clears the input each execution. Default is cleared.
ProgCasRatReq	BOOL	Program cascade/ratio mode request. Set by the user program to request Cascade/Ratio mode. When ProgValueReset is set, the instruction clears the input each execution. Default is cleared.
ProgAutoReq	BOOL	Program auto mode request. Set by the user program to request Auto mode. When ProgValueReset is set, the instruction clears the input each execution. Default is cleared.
ProgManualReq	BOOL	Program manual mode request. Set by the user program to request Manual mode. When ProgValueReset is set, the instruction clears the input each execution. Default is cleared.
ProgOverrideReq	BOOL	Program override mode request. Set by the user program to request Override mode. When ProgValueReset is set, the instruction clears the input each execution. Default is cleared.
ProgHandReq	BOOL	Program hand mode request. Set by the user program to request Hand mode. This value is usually read as a digital input from a hand/auto station. When ProgValueReset is set, the instruction clears the input each execution. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input each execution. Default is cleared.
OperOperReq	BOOL	Operator operator request. Set by the operator interface to request Operator control. The instruction clears this input each execution. Default is cleared.
OperCasRatReq	BOOL	Operator cascade/ratio mode request. Set by the operator interface to request Cascade/Ratio mode. The instruction clears this input each execution. Default is cleared.
OperAutoReq	BOOL	Operator auto mode request. Set by the operator interface to request Auto mode. The instruction clears the input each execution. Default is cleared.
OperManualReq	BOOL	Operator manual mode request. Set by the operator interface to request Manual mode. The instruction clears the input each execution. Default is cleared.
ProgValueReset	BOOL	Reset program control values. When set, all the program request inputs are cleared by the instruction each execution. When set and in Operator control, the instruction sets SPProgram = SP and CVProgram = CV. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0

Input Parameter:	Data Type:	Description:
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
CVEU	REAL	Scaled control variable output. Scaled using CVEUMax and CVEUMin, where CVEUMax corresponds to 100 percent and CVEUMin corresponds to 0 percent. This output typically controls an analog output module or a secondary loop. Arithmetic flags are set for this output. CVEU = (CV x CVEUSpan / 100) + CVEUMin CVEU span calculation: CVEUSpan = (CVEUMax - CVEUMin)
CV	REAL	Control variable output. This value is expressed as 0 to 100 percent. CV is limited by CVHLimit and CVLLimit when in auto or cascade/ratio mode or manual mode if CVManLimiting is set. Otherwise this value is limited by 0 and 100 percent. Arithmetic flags are set for this output.
CVInitializing	BOOL	Initialization mode indicator. CVInitializing is set when CVInitReq is set, during instruction first scan, and on a set to cleared transition of CVHealth (bad to good). CVInitializing is cleared after the instruction has been initialized and CVInitReq is cleared.
CVHAlarm	BOOL	CV high alarm indicator. Set when the calculated value of CV > 100 or CVHLimit.
CVLAlarm	BOOL	CV low alarm indicator. Set when the calculated value of CV < 0 or CVLLimit.
CVROCAlarm	BOOL	CV rate of change alarm indicator. Set when the calculated rate of change for CV exceeds CVROCLimit.
SP	REAL	Current setpoint value. The value of SP is used to control CV when in Auto or Cascade/Ratio mode.
SPPercent	REAL	The value of SP expressed in percent of span of PV. SPPercent = ((SP - PVEUMin) x 100) / PVSpan PV Span calculation: PVSpan = (PVEUMax - PVEUMin)
SPHAlarm	BOOL	SP high alarm indicator. Set when the SP > SPHLimit.
SPLAlarm	BOOL	SP low alarm indicator. Set when the SP < SPLLimit.
PVPercent	REAL	PV expressed in percent of span. PVPercent = ((PV- PVEUMin) x 100) / PVSpan PV Span calculation: PVSpan = (PVEUMax - PVEUMin)
E	REAL	Process error. Difference between SP and PV, scaled in PV units.
EPercent	REAL	The error expressed as a percent of span.
InitPrimary	BOOL	Initialize primary loop command. Set when not in Cascade/Ratio mode or when CVInitializing is set. This signal is normally used by the CVInitReq input of a primary PID loop.

Output Parameter:	Data Type:	Description:
WindupHOut	BOOL	Windup high indicator. Set when either a SP high, CV high, or CV low limit (depending on the control action) has been reached. This signal is typically used by the WindupHIn input to prevent the windup of the CV output on a primary loop.
WindupLOut	BOOL	Windup low indicator. Set when either a SP, CV high, or CV low limit (depending on the control action) has been reached. This signal is typically used by the WindupLIn input to prevent the windup of the CV output on a primary loop.
Ratio	REAL	Current ratio multiplier.
RatioHAlarm	BOOL	Ratio high alarm indicator. Set when Ratio > RatioHLimit.
RatioLAlarm	BOOL	Ratio low alarm indicator. Set when Ratio < RatioLLimit.
ZCDeadbandOn	BOOL	Zero crossing deadband indicator. When set the value of CV does not change. If ZCOff is set, then ZCDeadbandOn is set when | E | is within the ZCDeadband range. If ZCOff is cleared, then ZCDeadbandOn is set when | E | crosses zero and remains within the ZCDeadband range. ZCDeadbandOn is cleared when | E | exceeds the deadband range or when ZCDeadband = 0.
PVHHAlarm	BOOL	PV high-high alarm indicator. Set when PV ≥ PVHHLimit. Cleared when PV < (PVHHLimit - PVDeadband)
PVHAlarm	BOOL	PV high alarm indicator. Set when PV ≥ PVHLimit. Cleared when PV < (PVHLimit - PVDeadband)
PVLAlarm	BOOL	PV low alarm indicator. Set when PV ≤ PVLLimit. Cleared when PV > (PVLLimit + PVDeadband)
PVLLAlarm	BOOL	PV low-low alarm indicator. Set when PV ≤ PVLLLimit. Cleared when PV > (PVLLLimit + PVDeadband)
PVROCPosAlarm	BOOL	PV positive rate-of-change alarm indicator. Set when calculated PV rate-of-change ≥ PVROCPosLimit.
PVROCNegAlarm	BOOL	PV negative rate-of-change alarm indicator. Set when calculated PV rate-of-change ≤ (PVROCNegLimit x -1).
DevHHAlarm	BOOL	Deviation high-high alarm indicator. Set when PV ≥ (SP + DevHHLimit). Cleared when PV < (SP + DevHHLimit - DevDeadband)
DevHAlarm	BOOL	Deviation high alarm indicator. Set when PV ≥ (SP + DevHLimit). Cleared when PV < (SP + DevHLimit - DevDeadband)
DevLAlarm	BOOL	Deviation low alarm indicator. Set when PV ≤ (SP - DevLLimit). Cleared when PV > (SP - DevLLimit + DevDeadband)
DevLLAlarm	BOOL	Deviation low-low alarm indicator. Set when PV ≤ (SP - DevLLLimit). Cleared when PV > (SP - DevLLLimit + DevDeadband)
ProgOper	BOOL	Program/operator control indicator. Set when in Program control. Cleared when in Operator control.
CasRat	BOOL	Cascade/ratio mode indicator. Set when in the Cascade/Ratio mode.
Auto	BOOL	Auto mode indicator. Set when in the Auto mode.
Manual	BOOL	Manual mode indicator. Set when in the Manual mode.
Override	BOOL	Override mode indicator. Set when in the Override mode.
Hand	BOOL	Hand mode indicator. Set when in the Hand mode.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status1	DINT	Status of the function block.

Output Parameter:	Data Type:	Description:
InstructFault (Status1.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
PVFaulted (Status1.1)	BOOL	Process variable (PV) health bad.
CVFaulted (Status1.2)	BOOL	Control variable (CV) health bad.
HandFBFaulted (Status1.3)	BOOL	HandFB value health bad.
PVSpanInv (Status1.4)	BOOL	Invalid span of PV. PVEUMax ≤ PVEUMin.
SPProgInv (Status1.5)	BOOL	SPProg < SPLLimit or SPProg > SPHLimit. The instruction uses the limited value for SP.
SPOperInv (Status1.6)	BOOL	SPOper < SPLLimit or SPOper > SPHLimit. The instruction uses the limited value for SP.
SPCascadeInv (Status1.7)	BOOL	SPCascade < SPLLimit or SPCascade > SPHLimit. The instruction uses the limited value for SP.
SPLimitsInv (Status1.8)	BOOL	Limits invalid: SPLLimit < PVEUMin, SPHLimit > PVEUMax, or SPHLimit < SPLLimit. If SPHLimit < SPLLimit, the instruction limits the value using SPLLimit
RatioProgInv (Status1.9)	BOOL	RatioProg < RatioLLimit or RatioProg > RatioHLimit. The instruction limits the value for Ratio.
RatioOperInv (Status1.10)	BOOL	RatioOper < RatioLLimit or RatioOper > RatioHLimit. The instruction limits the value for Ratio.
RatioLimitsInv (Status1.11)	BOOL	Low limit < 0 or High limit < low limit.
CVProgInv (Status1.12)	BOOL	CVProg < 0 or CVProg > 100, or CVProg < CVLLimit or CVProg > CVHLimit when CVManLimiting is set. The instruction limits the value for CV.
CVOperInv (Status1.13)	BOOL	CVOper < 0 or CVOper > 100, or CVOper < CVLLimit or CVOper > CVHLimit when CVManLimiting is set. The instruction limits the value for CV.
CVOverrideInv (Status1.14)	BOOL	CVOverride < 0 or CVOverride > 100. The instruction limits the value for CV.
CVPreviousInv (Status1.15)	BOOL	CVPrevious < 0 or CVPrevious > 100, or < CVLLimit or > CVHLimit when in auto or cascade/ratio mode. The instruction uses the limited value for CV_{n-1}.
CVEUSpanInv (Status1.16)	BOOL	Invalid CVEU span. The instruction uses a value of CVEUMax = CVEUMin.
CVLimitsInv (Status1.17)	BOOL	CVLLimit < 0, CVHLimit > 100, or CVHLimit < CVLLimit. If CVHLimit < CVLLimit, the instruction limits CV using CVLLimit.
CVROCLimitInv (Status1.18)	BOOL	CVROCLimit < 0. The instruction disables ROC limiting.
FFInv (Status1.19)	BOOL	FF < –100 or FF > 100. The instruction uses the limited value for FF.
FFPreviousInv (Status1.20)	BOOL	FFPrevious < –100 or FFPrevious > 100. The instruction uses the limited value for FF_{n-1}.
HandFBInv (Status1.21)	BOOL	HandFB < 0 or HandFB > 100. The instruction uses the limited value for CV.
PGainInv (Status1.22)	BOOL	PGain < 0. The instruction uses a value of PGain = 0.
IGainInv (Status1.23)	BOOL	IGain < 0. The instruction uses a value of IGain = 0.
DGainInv (Status1.24)	BOOL	DGain < 0. The instruction uses a value of DGain = 0.
ZCDeadbandInv (Status1.25)	BOOL	ZCDeadband < 0. The instruction disables zero crossing deadband.

Output Parameter:	Data Type:	Description:
PVDeadbandInv (Status1.26)	BOOL	PVDeadband < 0.
PVROCLimitsInv (Status1.27)	BOOL	PVROCPosLimit < 0, PVROCNegLimit < 0, or PVROCPeriod < 0.
DevHLLimitsInv (Status1.28)	BOOL	Deviation high-low limits invalid. Low-low limit < 0, low limit < 0, high limit < 0, or high-high limit < 0. The instruction uses 0 for the invalid limit.
DevDeadbandInv (Status1.29)	BOOL	Deviation deadband < 0. The instruction uses a value of DevDeadband = 0.
Status2	DINT	Timing status of the function block.
TimingModeInv (Status2.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status2.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status2.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status2.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status2.31)	BOOL	Invalid DeltaT value.

Description:

The PID algorithm regulates the CV output in order to maintain the PV at the SP when the instruction executes in Cascade/Ratio or Auto modes.

When ControlAction is set, the calculated value of EPercent and PVPIDPercent is negated before being used by the control algorithm.

The following table describes how the instruction calculates the PID terms:

PID term:	How calculated:
proportional	The proportional term is calculated using: • PV when PVEProportional is set or • Error when PVEProportional is cleared Set PGain = 0 to disable proportional control.
integral	The integral term is calculated using Error. Set IGain = 0 to disable integral control. Also, setting PGain = 0 when DependIndepend is set will disable integral control.
derivative	The derivative term is calculated using: • PV when PVEDerivative is set or • Error when PVEDerivative is cleared Set DGain = 0 to disable derivative control. Also, setting PGain = 0 when DependIndepend is set will disable derivative control. Derivative smoothing is enabled when DSmoothing is set and disabled when DSmoothing is cleared. Derivative smoothing causes less CV output “jitter” as a result of a noisy PV signal but also limits the effectiveness of high derivative gains.

Computing CV

The PID control algorithm computes the value for CV by summing Delta PTerm, Delta ITerm, Delta DTerm, and CV from the previous execution of the instruction (i.e. CV_{n-1}). When CVSetPrevious is set, CV_{n-1} is set equal to CVPrevious. This lets you preset CV_{n-1} to a specified value before computing the value of CV.

$$CalculatedCV = CV_{n-1} + \Delta PTerm + \Delta ITerm + \Delta DTerm$$

PIDE algorithms

The PIDE instruction uses a velocity form PID algorithm similar to that used in most DCS systems. Some advantages to a velocity form algorithm include:

- bumpless adaptive gain changes – You can change gains on the fly without initializing the algorithm.
- multi-loop control schemes – You can implement cross limiting between loops by manipulating the CV_{n-1} term.

Independent Gains Form

$$CV_n = CV_{n-1} + K_P \Delta E + \frac{K_I}{60} E\Delta t + 60K_D \frac{E_n - 2E_{n-1} + E_{n-2}}{\Delta t}$$

In this form of the algorithm, each term of the algorithm (proportional, integral, and derivative), has a separate gain. Changing one gain only affects that term and not any of the others, where:

PIDE term:	Description:
CV	control variable
E	error in percent of span
Δt	update time in seconds used by the loop
K_P	proportional gain
K_I	integral gain in min^{-1} a larger value of K_I causes a faster integral response.
K_D	derivative gain in minutes

Dependent Gains Form

$$CV_n = CV_{n-1} + K_C\left(\Delta E + \frac{1}{60T_I}E\Delta t + 60T_D\frac{E_n - 2E_{n-1} + E_{n-2}}{\Delta t}\right)$$

This form of the algorithm, changes the proportional gain into a controller gain. By changing the controller gain, you change the action of all three terms (proportional, integral, and derivative) at the same time., where:

PIDE term:	Description:
CV	control variable
E	error in percent of span
Δt	update time in seconds used by the loop
K_C	controller gain
T_I	integral time constant in minutes per repeat a larger value of T_I causes a slower integral response It takes T_I minutes for the integral term to repeat the action of the proportional term in response to a step change in error.
T_D	derivative time in constant in minutes

Determining which algorithm to use

When the PIDE parameter DependIndepend is cleared, the parameters PGain, IGain, and DGain represent K_P, K_I, and K_D. When DependIndepend is set, the parameters PGain, IGain, and DGain represent K_C, T_I, and T_D.

The PIDE equations above are representative of the algorithms used by the PIDE instruction. You can substitute the change in error values for the change in PV (in percent of span) for the proportional and derivative terms by manipulating the parameters PVEProportional and PVEDerivative. By default, the PIDE instruction uses the change in error for the proportional term and the change in PV for the derivative term. This eliminates large derivative spikes on changes in setpoint.

You can convert the gains used between the different PIDE algorithm forms using these equations:

- $K_P = K_C$
- $K_I = \frac{K_C}{T_I}$
- $K_D = K_C T_D$

Each algorithm provides identical control with the appropriate gains. Some people prefer the independent gains style because they can manipulate individual gains without affecting the other terms. Others prefer the dependent gains style because they can, at least to a certain extent, change just the controller gain and cause an overall change in the aggressiveness of the PID loop without changing each gain separately.

Monitoring the PIDE instruction

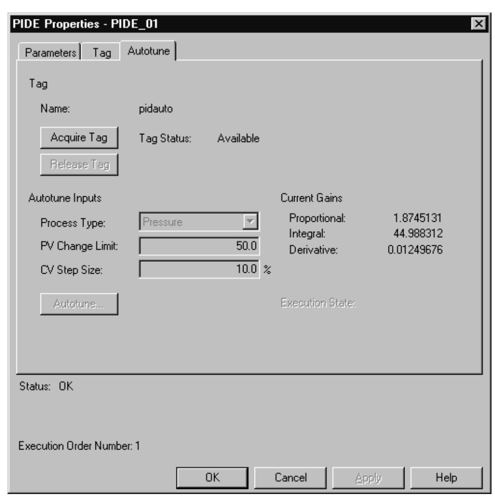
There is an operator faceplate available for the PIDE instruction. For more information, see appendix Function Block Faceplate Controls.

Autotuning the PIDE instruction

The RSLogix 5000 PIDE autotuner provides an open-loop autotuner built into the PIDE instruction. You can autotune from PanelView terminals or any other operator interface devices, as well as RSLogix 5000 software. The PIDE block has an Autotune Tag (type PIDE_AUTOTUNE) that you specify for those PIDE blocks that you want to autotune.

The PIDE autotuner is installed with RSLogix 5000 software, but you need an activation key to enable the autotuner. The autotuner is only supported in function block programming; it is not available in relay ladder or structured text programming.

Use the Autotune tab to specify and configure the autotune tag for a PIDE block.



For more information about using the autotuner, see RSLogix 5000 online help or the *Getting Results with the PIDE Autotuner*, publication PIDE-GR001.

Arithmetic Status Flags: Arithmetic status flags are set for the CV output.

Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	InstructionFirstScan is set	InstructionFirstScan is set
instruction first scan	If CVFault and CVEUSpanInv are set, see Processing Faults 11-76. If CVFault and CVEUSpanInv are cleared 1. CVInitializing is set. 2. If PVFault is set, PVSpanInv and SPLimitsInv are cleared. See Processing Faults on page 1-76. 3. The PID control algorithm is not executed. 4. The instruction sets CVEU = CVInitValue and CV = corresponding percentage. CVInitValue is not limited by CVEUMax or CVEUMin. When the instruction calculates CV as the corresponding percentage, it is limited to 0-100. $CVEU = CVInitValue$ $CV_{n-1} = CV = \frac{CVEU - CVEUMin}{CVEUMax - CVEUMin} \times 100$ $CVOper = CV$ 5. When CVInitializing and ManualAfterInit are set, the instruction disables auto and cascade/ratio modes. If the current mode is not Override or Hand mode, the instruction changes to Manual mode. If ManualAfterInit is cleared the mode is not changed. 6. All the operator request inputs are cleared. 7. If ProgValueReset set, all the program request inputs are cleared 8. All the PV high-low, PV rate-of-change, and deviation high-low alarm outputs are cleared. 9. If CVInitReq is cleared, CVInitializing is cleared.	
instruction first run	ProgOper is cleared. The instruction changes to manual mode.	ProgOper is cleared. The instruction changes to manual mode.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

When CVInitReq is set, or during instruction first scan, or on a set to cleared transition of CVFault (bad to good), the instruction initializes the CVEU and CV outputs to the value of CVInitValue. If the timing mode is not oversample and EnableIn transitions from cleared to set, the instruction initializes the CVEU and CV values. CVInitialization is cleared after the initialization and when CVInitReq is cleared.

The CVInitValue normally comes from the analog output's readback value. The CVInitReq value normally comes from the "In Hold" status bit on the analog output controlled by CVEU. The initialization procedure is performed to avoid a bump at startup in the output signal being sent to the field device.

The instruction does not initialize and the CVEU and CV values are not updated if CVFault or CVEUSpanInv is set.

When using cascaded PID loops, the primary PID loop can be initialized when the secondary loop is initialized or when the secondary loop leaves the Cascade/Ratio mode. In this case, move the state of the InitPrimary output and SP output from the secondary loop to the CVInitReq input and CVInitValue input on the primary loop.

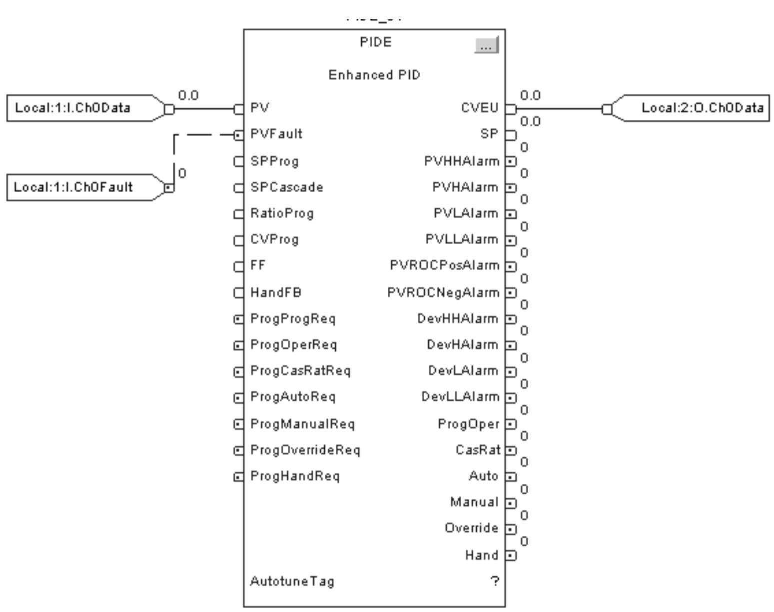
Example 1: The easiest way to implement a PIDE instruction is to create an function block routine in a program in a periodic task. The default timing mode for the PIDE instruction is periodic. When the PIDE instruction is used in a periodic task and in periodic timing mode, it automatically uses the periodic task's update rate as its DeltaT update time. All you need to do is wire the process variable analog input into the PV parameter on the PIDE instruction and wire the CVEU out of the PIDE instruction into the controlled variable analog output.

Optionally, you can wire the analog input's fault indicator (if one is available) into the PVFault parameter on the PIDE instruction. This forces the PIDE into Manual mode when the analog input is faulted and stops the PIDE CVEU output from winding up or down when the PV signal is not available.

Structured Text

```
PIDE_01.PV := Local:1:I.Ch0Data;
PIDE_01.PVFault := Local:1:I.Ch0Fault;
PIDE(PIDE_01);
Local:2:O.Ch0Data := PIDE_01.CVEU;
```

Function Block



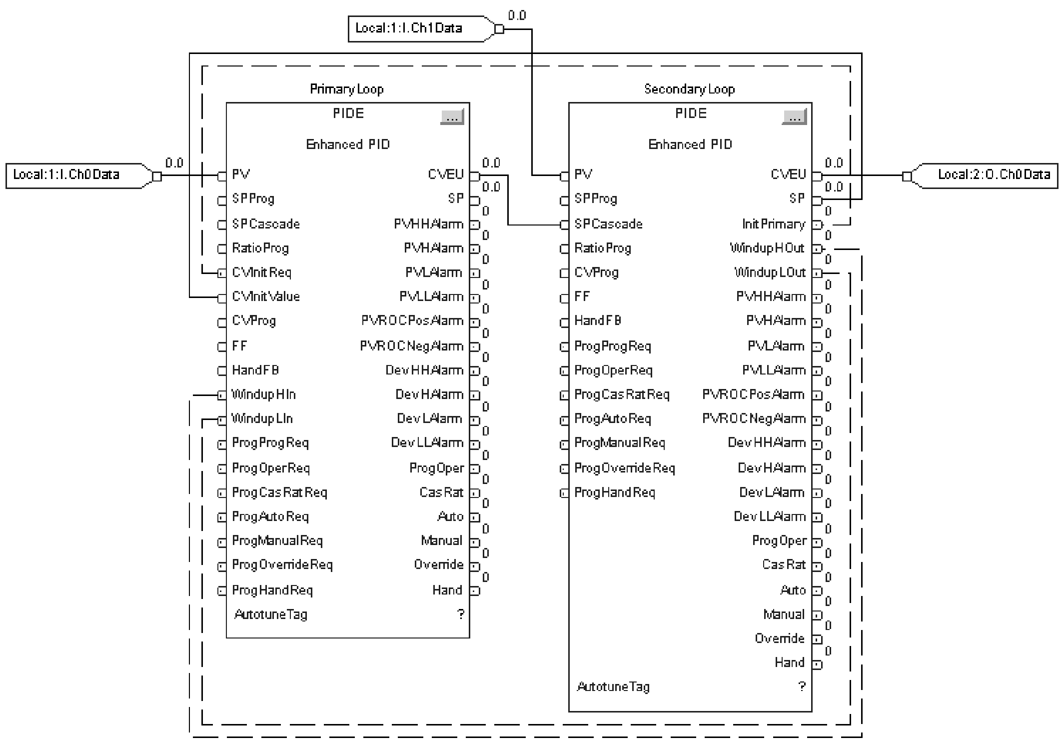
Example 2: Cascade control is useful when externally-caused upsets to the controlled variable occur often, which then cause upsets to the process variable you are trying to control. For example, try to control the temperature of liquid in a tank by varying the amount of steam fed into a heating jacket around the tank. If the steam flow suddenly drops because of an upstream process, the temperature of the liquid in the tank eventually drops and the PIDE instruction then opens the steam valve to compensate for the drop in temperature.

In this example, a cascaded loop provides better control by opening the steam valve when the steam flow drops *before* the liquid temperature in the tank drops. To implement a cascaded loop, use a PIDE instruction to control the steam valve opening based on a process variable signal from a steam flow transmitter. This is the secondary loop of the cascaded pair. A second PIDE instruction (called the primary loop) uses the liquid temperature as a process variable and sends its CV output into the setpoint of the secondary loop. In this manner, the primary temperature loop asks for a certain amount of steam flow from the secondary steam flow loop. The steam flow loop is then responsible for providing the amount of steam requested by the temperature loop in order to maintain a constant liquid temperature.

Structured Text

```
PrimaryLoop.PV := Local:1:I.CH0Data;
PrimaryLoop.CVInitReq := SecondaryLoop.InitPrimary;
PrimaryLoop.CVInitValue := SecondaryLoop.SP;
PrimaryLoop.WindupHIn := SecondaryLoop.WindupHOut;
PrimaryLoop.WindupLIn := SecondaryLoop.WindupLOut;

PIDE(PrimaryLoop);

SecondaryLoop.PV := Local:1:I.Ch1Data;
SecondaryLoop.SPCascade := PrimaryLoop.CVEU;

PIDE(SecondaryLoop);

Local:2:O.Ch0Data:= SecondaryLoop.CVEU;
```

Function Block



For a cascaded pair of loops to work correctly, the secondary loop must have a faster process response than the primary loop. This is because the secondary loop's process must be able to compensate for any upsets before these upsets affect the primary loop's process. In this example, if steam flow drops, the steam flow must be able to increase as a result of the secondary controller's action before the liquid temperature is affected.

To set up a pair of cascaded PIDE instructions, set the AllowCasRat input parameter in the secondary loop. This allows the secondary loop to be placed into Cascade/Ratio mode. Next, wire the CVEU from the primary loop into the SPCascade parameter on the secondary loop. The SPCascade value is used as the SP on the secondary loop when the secondary loop is placed into Cascade/Ratio mode. The engineering unit range of the CVEU on the primary loop should match the engineering unit range of the PV on the secondary loop. This lets the primary loop scale its 0-100% value of CV into the matching engineering units used for the setpoint on the secondary loop.

The PIDE instruction supports several other features to more effectively support cascade control. Wire the InitPrimary output on the secondary loop into the CVInitReq input on the primary loop and wire the SP output of the secondary into the CVInitValue input on the primary. This sets the CVEU value of the primary loop equal to the SP of the secondary loop when the secondary loop leaves Cascade/Ratio mode. This allows a bumpless transfer when you place the secondary loop back into Cascade/Ratio mode. Also, wire the WindupHOut and WindupLOut outputs on the secondary loop into the WindupHIn and WindupLIn inputs on the primary loop. This causes the primary loop to stop increasing or decreasing, as appropriate, its value of CVEU if the secondary loop hits a SP limit or CV limit and eliminates any windup on the primary loop if these conditions occur.

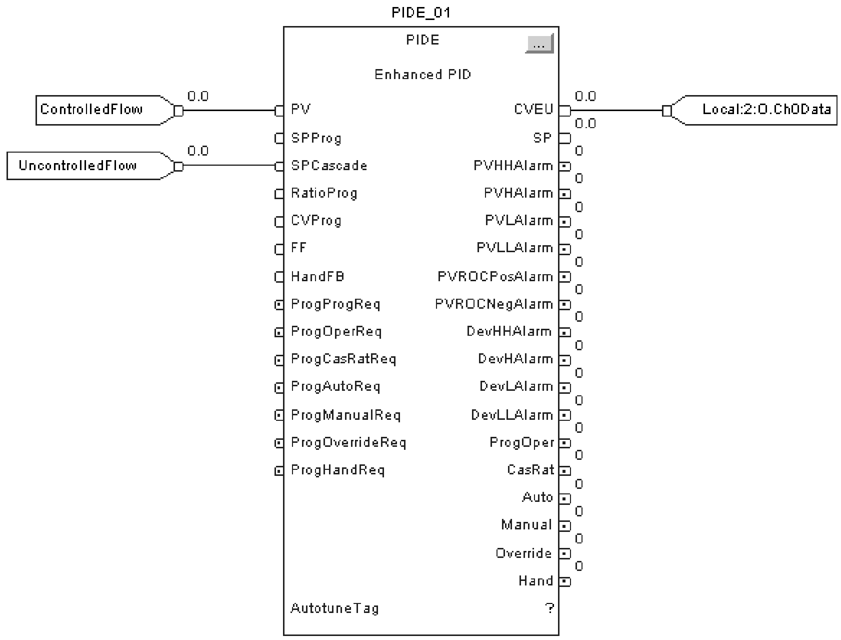
Example 3: Ratio control is typically used to add a fluid in a set proportion to another fluid. For example, if you want to add two reactants (say A and B) to a tank in a constant ratio, and the flow rate of reactant A may change over time because of some upstream process upsets, you can use a ratio controller to automatically adjust the rate of reactant B addition. In this example, reactant A is often called the "uncontrolled" flow since it is not controlled by the PIDE instruction. Reactant B is then called the "controlled" flow.

To perform ratio control with a PIDE instruction, set the AllowCasRat and UseRatio input parameters. Wire the uncontrolled flow into the SPCascade input parameter. When in Cascade/Ratio mode, the uncontrolled flow is multiplied by either the RatioOper (when in Operator control) or the RatioProg (when in Program control) and the resulting value is used by the PIDE instruction as the setpoint.

Structured Text

```
PIDE_01.PV := ControlledFlow;
PIDE_01.SPCascade := UncontrolledFlow;

PIDE(PIDE_01);

Local:2:O.Ch0Data := PIDE_01.CVEU;
```

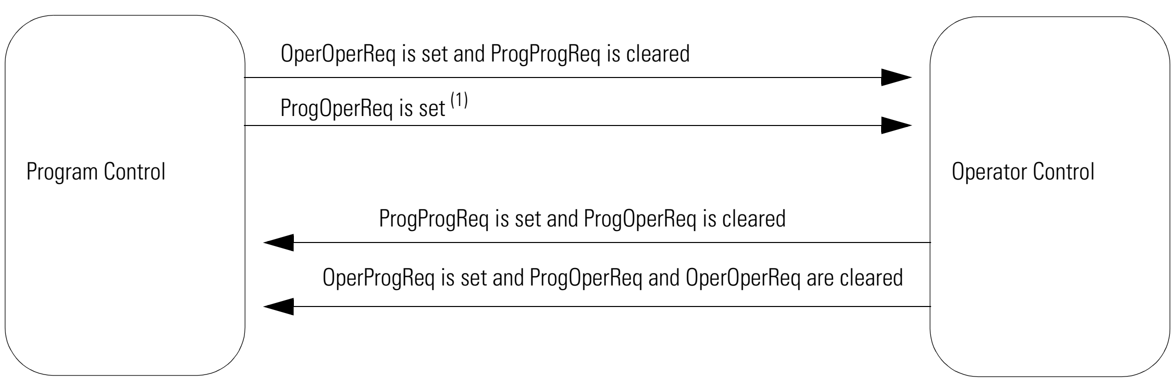
Function Block



Switching between Program control and Operator control

The PIDE instruction can be controlled by either a user program or an operator interface. You can change the control mode at any time. Program and Operator control use the same ProgOper output. When ProgOper is set, control is Program; when ProgOper is cleared, control is Operator.

The following diagram shows how the PIDE instruction changes between Program control and Operator control.



(1) The instruction remains in Operator control mode when ProgOperReq is set.

For more information on program and operator control, see page B-13.

Operating modes

The PIDE instruction supports these PID modes:

PID Operating Mode:	Description:
Cascade/Ratio	While in Cascade/Ratio mode the instruction computes the change in CV. The instruction regulates CV to maintain PV at either the SPCascade value or the SPCascade value multiplied by the Ratio value. SPCascade comes from either the CVEU of a primary PID loop for cascade control or from the "uncontrolled" flow of a ratio-controlled loop. Select Cascade/Ratio mode using either OperCasRatReq or ProgCasRatReq: Set OperCasRatReq to request Cascade/Ratio mode. Ignored when ProgOper, ProgOverrideReq, ProgHandReq, OperAutoReq, or OperManualReq is set, or when AllowCasRat is cleared. Set ProgCasRatReq to request Cascade/Ratio mode. Ignored when ProgOper or AllowCasRat is cleared or when ProgOverrideReq, ProgHandReq, ProgAutoReq, or ProgManualReq is set.
Auto	While in Auto mode the instruction computes the change in CV. The instruction regulates CV to maintain PV at the SP value. If in program control, SP = SPProg; if in Operator control, SP = SPOper. Select Auto mode using either OperAutoReq or ProgAutoReq: Set OperAutoReq to request Auto mode. Ignored when ProgOper, ProgOverrideReq, ProgHandReq, or OperManualReq is set. Set ProgAutoReq to request Auto mode. Ignored when ProgOper is cleared or when ProgOverrideReq, ProgHandReq, or ProgManualReq is set.
Manual	While in Manual mode the instruction does not compute the change in CV. The value of CV is determined by the control. If in Program control, CV = CVProg; if in Operator control, CV = CVOper. Select Manual mode using either OperManualReq or ProgManualReq: Set OperManualReq to request Manual mode. Ignored when ProgOper, ProgOverrideReq, or ProgHandReq is set. Set ProgManualReq to request Manual mode. Ignored when ProgOper is cleared or when ProgOverrideReq or ProgHandReq is set.
Override	While in Override mode the instruction does not compute the change in CV. CV = CVOverride, regardless of the control mode. Override mode is typically used to set a "safe state" for the PID loop. Select Override mode using ProgOverrideReq: Set ProgOverrideReq to request Override mode. Ignored when ProgHandReq is cleared.
Hand	While in Hand mode the PID algorithm does not compute the change in CV. CV = HandFB, regardless of the control mode. Hand mode is typically used to indicate that control of the final control element was taken over by a field hand/auto station. Select Hand mode using ProgHandReq: Set ProgHandReq to request hand mode. This value is usually read as a digital input from a hand/auto station.

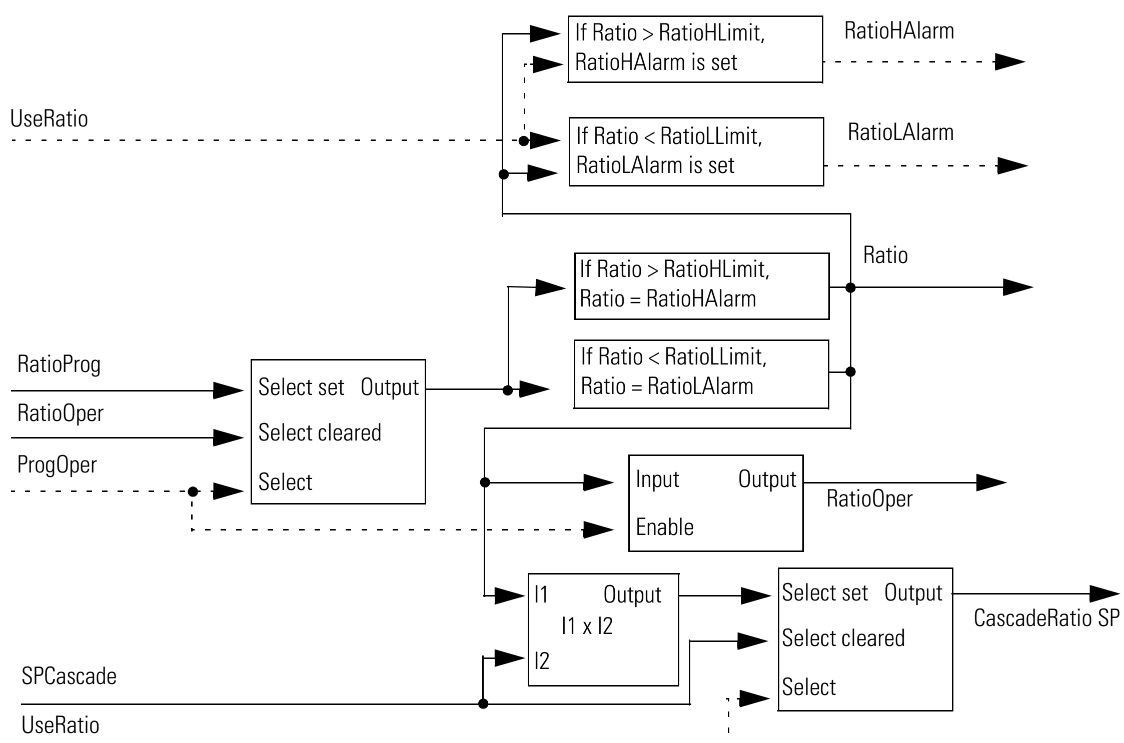
The Cascade/Ratio, Auto, and Manual modes can be controlled by a user program when in Program control or by an operator interface when in Operator control. The Override and Hand modes have a mode request input that can only be controlled by a user program; these inputs operate in both Program and Operator control.

Selecting the setpoint

Once the instruction determines program or operator control and the PID mode, the instruction can obtain the proper SP value. You can select the cascade/ratio SP or the current SP.

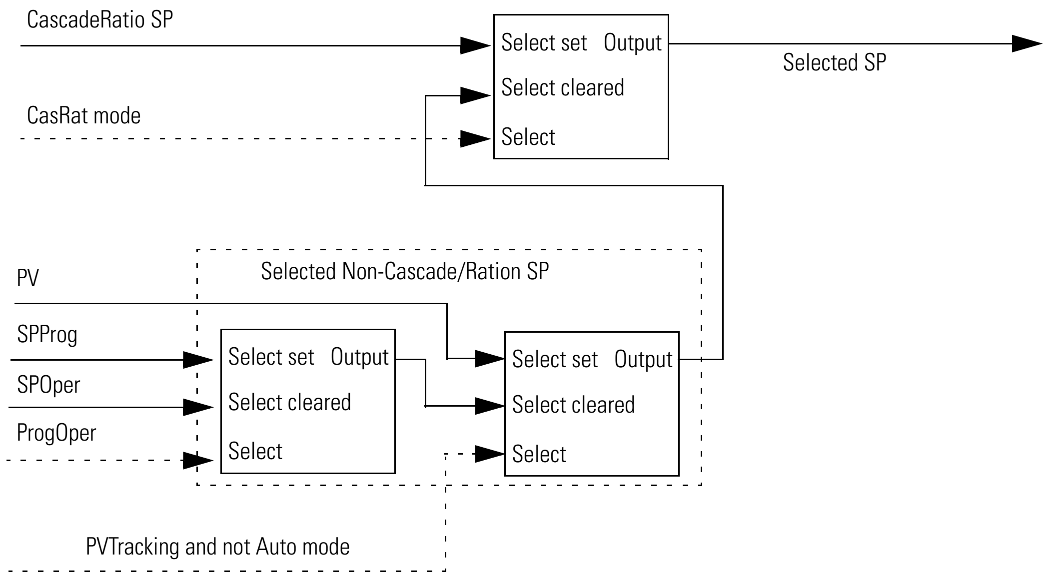
Cascade/ratio SP

The cascade/ratio SP is based on the UseRatio and ProgOper values.



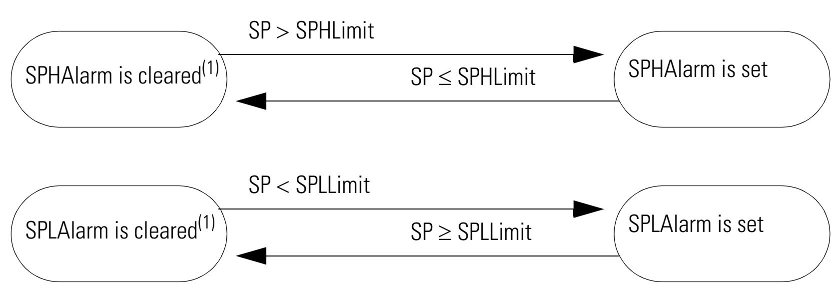
Current SP

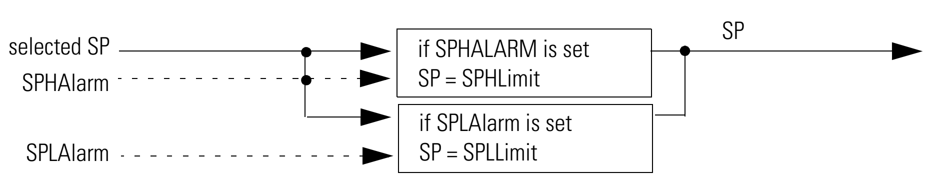
The current SP is based on the Cascade/Ratio mode, the PVTracking value, auto mode, and the ProgOper value.



SP high/low limiting

The high-to-low alarming algorithm compares SP to the SPHLimit and SPLLimit alarm limits. SPHLimit cannot be greater than PVEUMax and SPLLimit cannot be less than PVEUMin.

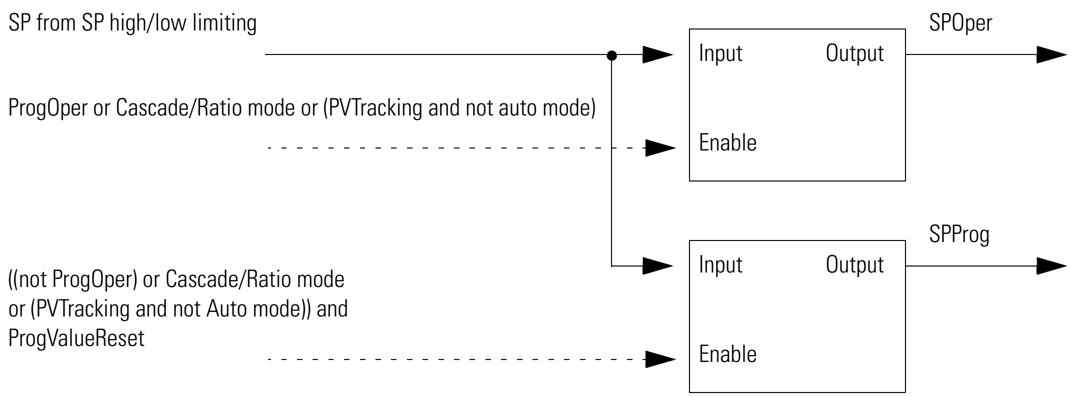




(1) During instruction first scan, the instruction clears the SP alarm outputs. The instruction also clears the SP alarm limits and disables the alarming algorithm when PVSpanInv is set.

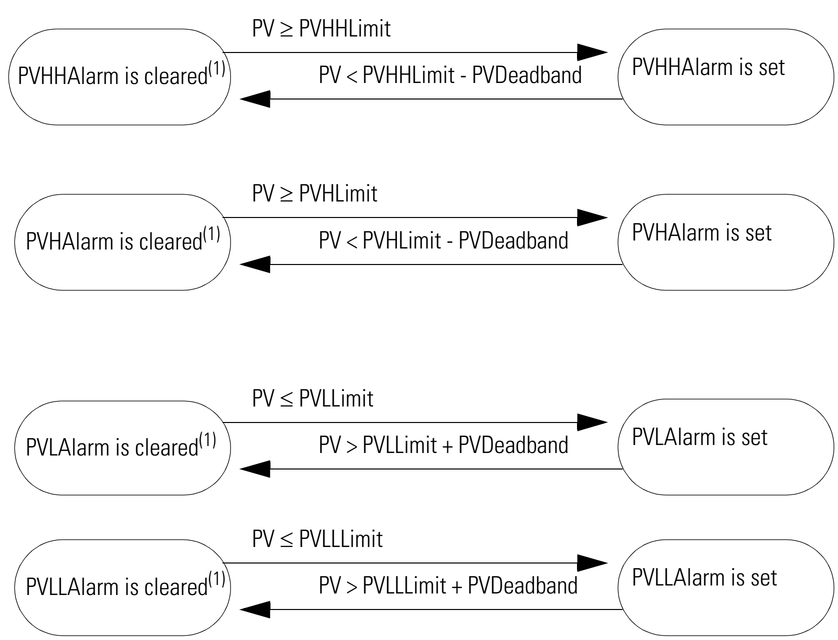
Updating the SPOper and SPProg values

The PIDE instruction makes SPOper = SP or SPProg = SP to obtain bumpless control switching between Program and Operator control or when switching from Cascade/Ratio mode.



PV high/low alarming

The high-high to low-low alarming algorithm compares PV to the PV alarm limits and the PV alarm limits plus or minus the PV alarm deadband.



(1) During instruction first scan, the instruction clears all the PV alarm outputs. The instruction also clears the PV alarm outputs and disables the alarming algorithm when PVFaulted is set.

PV rate-of-change alarming

PV rate-of-change (ROC) alarming compares the change in the value of PV over the PVROCPeriod against the PV positive and negative rate-of-change limits. The PVROCPeriod provides a type of deadband for the rate-of-change alarm. For example, if you use a ROC alarm limit of 2°F/second with a period of execution of 100 ms, and an analog input module with a resolution of 1°F, then every time the input value changes, a ROC alarm is generated because the instruction sees a rate of 10°F/second. However, by entering a PVROCPeriod of at least 1 sec, the ROC alarm is only generated if the rate truly exceeds the 2°F/second limit.

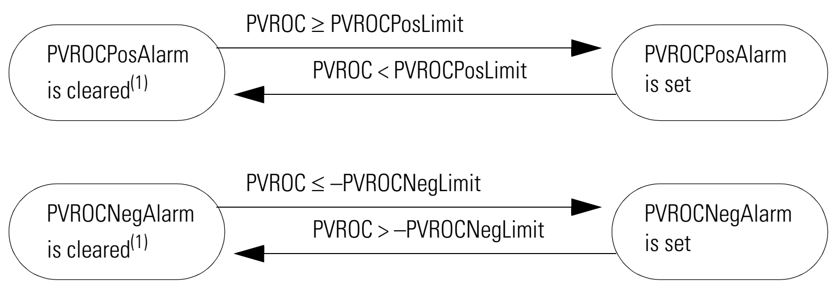
The ROC calculation is only performed when the PVROCPeriod has expired. The rate-of-change is calculated as:

$$ElapsedROCPeriod = ElapsedROCPeriod + ElapsedTimeSinceLastExecution$$

If ElapsedROCPeriod ≥ PVROCPeriod then:

This value:	Is:
PVROC	$\frac{PV_n - PVROC_{n-1}}{PVROCPeriod}$
$PVROC_{n-1}$	$PVROC_{n-1} = PV_n$
ElapsedROCPeriod	$ElapsedROCperiod = 0$

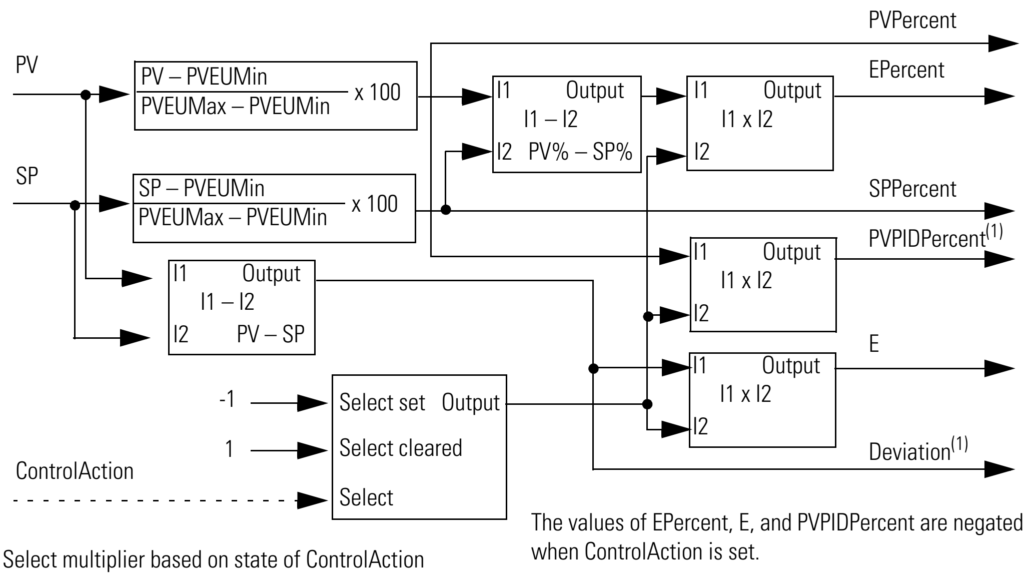
Once PVROC has been calculated, the PV ROC alarms are determined as follows:



(1) During instruction first scan, the instruction clears the PV ROC alarm outputs. The instruction also clears the PVROC alarm outputs and disables the PV ROC alarming algorithm when PVFaulted is set.

Converting the PV and SP values to percent

The instruction converts PV and SP to a percent and calculates the error before performing the PID control algorithm. The error is the difference between the PV and SP values. When ControlAction is set, the values of EPercent, E, and PVPIDPercent are negated before being used by the PID algorithm.

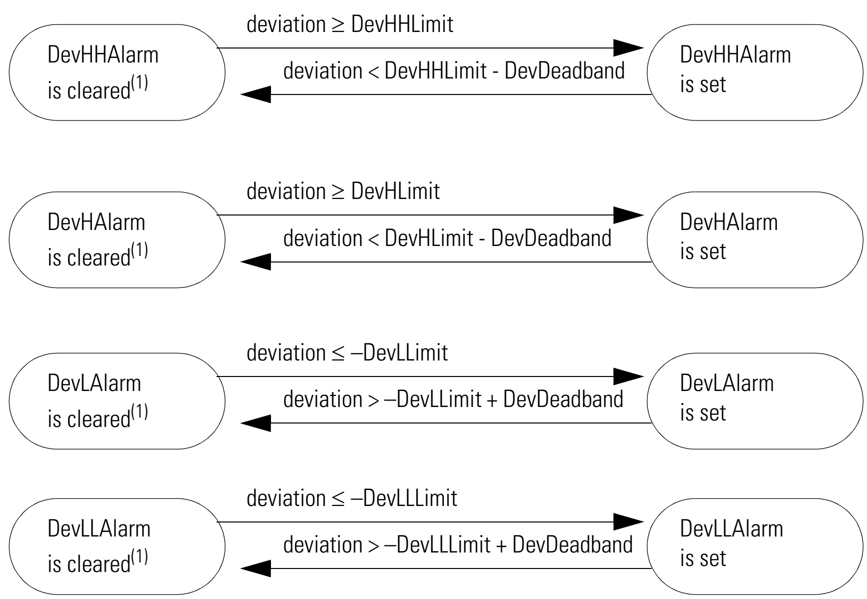


(1) PVPIDPercent and Deviation are internal parameters used by the PID control algorithm.

Deviation high/low alarming

Deviation is the difference in value between the process variable (PV) and setpoint (SP). Deviation alarming alerts the operator to a discrepancy between the process variable and the setpoint value.

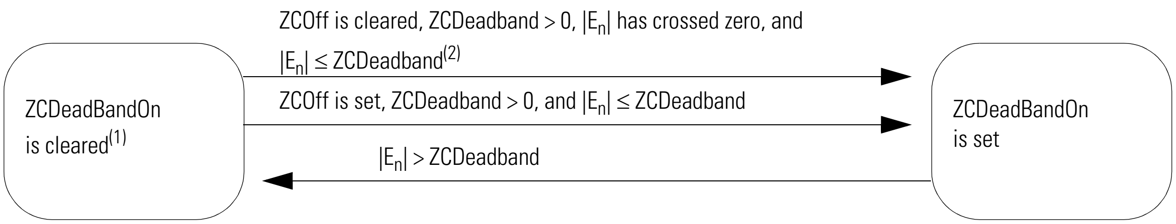
The high-high to low-low alarming algorithm compares the deviation to deviation alarm limits and the deviation alarm limits plus or minus the deadband.

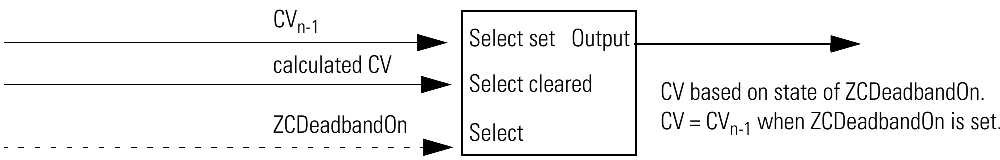


(1) During instruction first scan, the instruction clears the deviation alarm outputs. The instruction also clears the deviation alarm outputs and disables the alarming algorithm when PVFaulted or PVSpanInv is set.

Zero crossing deadband control

You can limit CV such that its value does not change when error remains within the range specified by ZCDeadband ($|E| \leq$ ZCDeadband).





(1) When ZCOff is cleared, ZCDeadband > 0, error has crossed zero for the first time, (i.e. $E_n \geq 0$ and $E_{n-1} < 0$ or when $E_n \leq 0$ and $E_{n-1} > 0$), and $|E_n| \leq$ ZCDeadband, the instruction sets ZCDeadbandOn.

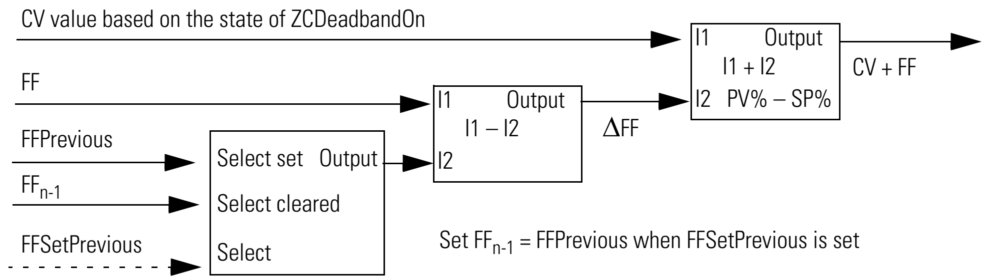
(2) On the transition to Auto or Cascade/Ratio mode, the instruction sets $E_{n-1} = E_n$.

The instruction disables the zero crossing algorithm and clears ZCDeadbandOn under these conditions:

- during instruction first scan
- ZCDeadband ≤ 0
- Auto or Cascade/Ratio is not the current mode
- PVFaulted is set
- PVSpanInv is set

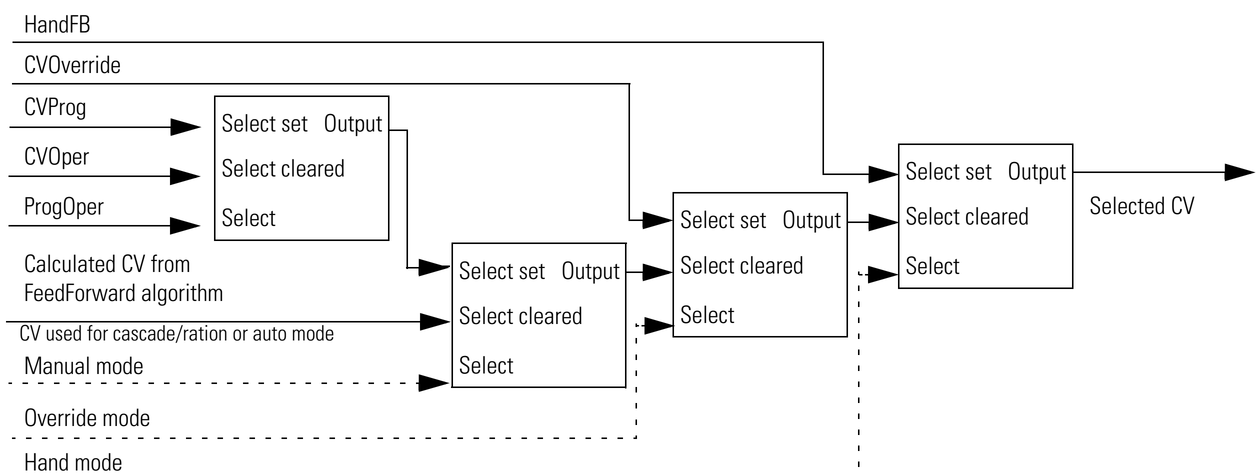
Feedforward control

Compute CV by summing CV from the zero crossing algorithm with ΔFF. The value of ΔFF = FF - FF_{n-1}. When FFSetPrevious is set, FF_{n-1} = FFPrevious. This lets you preset FF_{n-1} to a specified value before the instruction calculates the value of ΔFF.



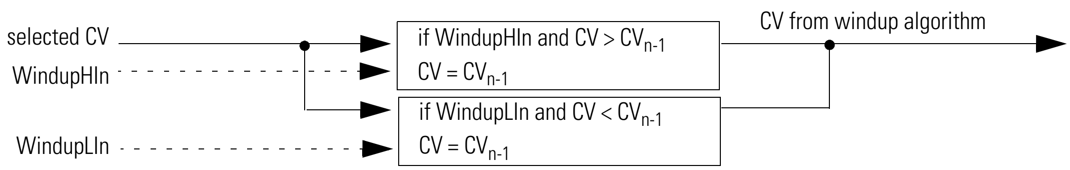
Selecting the control variable

Once the PID algorithm has been executed, select the CV based on program or operator control and the current PID mode.



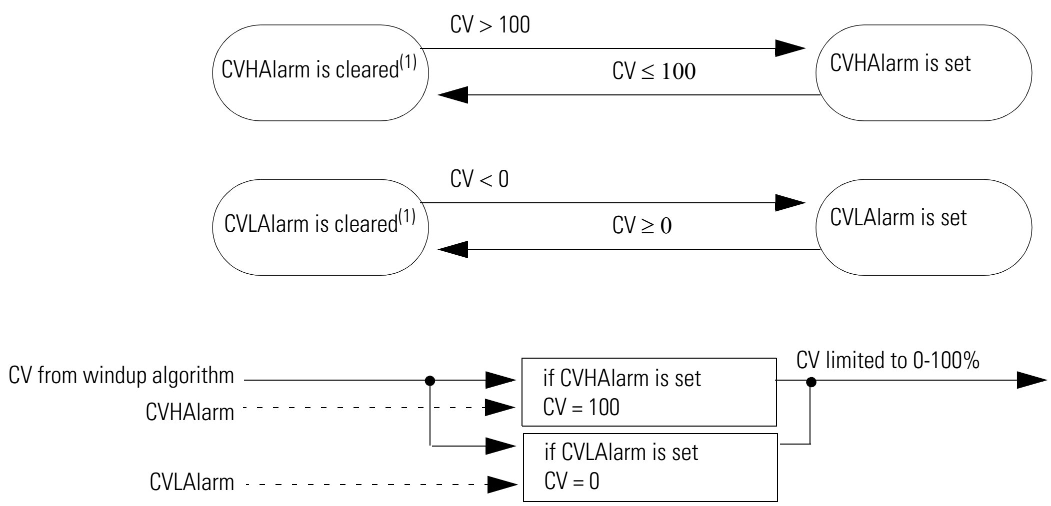
CV windup limiting

Limit the CV such that its value cannot increase when WindupHIn is set or decrease when WindupLIn is set. These inputs are typically the WindupHOut or WindupLOut outputs from a secondary loop. The WindupHIn and WindupLIn inputs are ignored if CVInitializing, CVFault, or CVEUSpanInv is set.



CV percent limiting

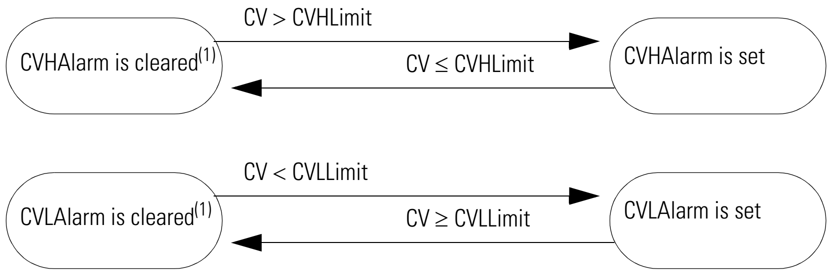
The following diagram illustrates how the instruction determines CV percent limiting.

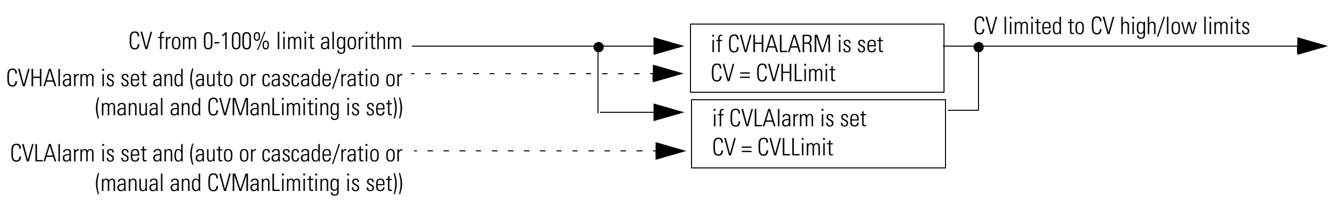


(1) During instruction first scan, the instruction clears the alarm outputs.

CV high/low limiting

The instruction always performs alarming based on CVHLimit and CVLLimit. Limit CV by CVHLimit and CVLLimit when in auto or cascade/ratio mode. When in manual mode, limit CV by CVHLimit and CVLLimit when CVManLimiting is set. Otherwise limit CV by 0 and 100 percent.





(1) During instruction first scan, the instruction clears the alarm outputs.

CV rate-of-change limiting

The PIDE instruction limits the rate-of-change of CV when in Auto or Cascade/Ratio mode or when in Manual mode and CVManLimiting is set. A value of zero disables CV rate-of-change limiting.

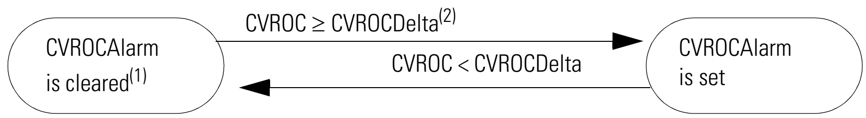
The CV rate-of-change is calculated as:

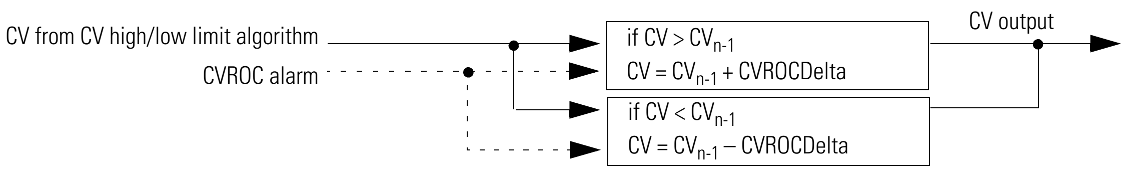
$$CVROC = |CV_n - CV_{n-1}|$$

$$CVROCDelta = CVROCLimit \times DeltaT$$

where DeltaT is in seconds.

Once CV rate-of-change has been calculated, the CV rate-of-change alarms are determined as follows:



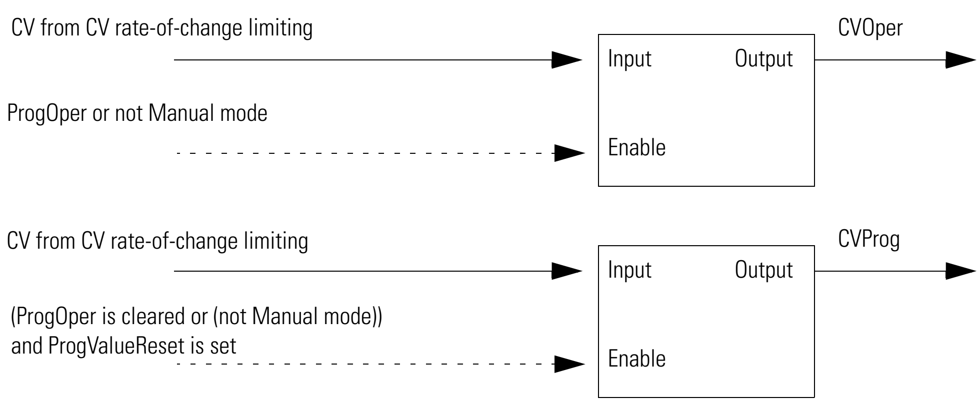


(1) During instruction first scan, the instruction clears the alarm output. The instruction also clears the alarm output and disables the CV rate-of-change algorithm when CVInitializing is set.

(2) When in Auto or Cascade/Ratio mode or when in Manual mode and CVManLimiting is set, the instruction limits the change of CV.

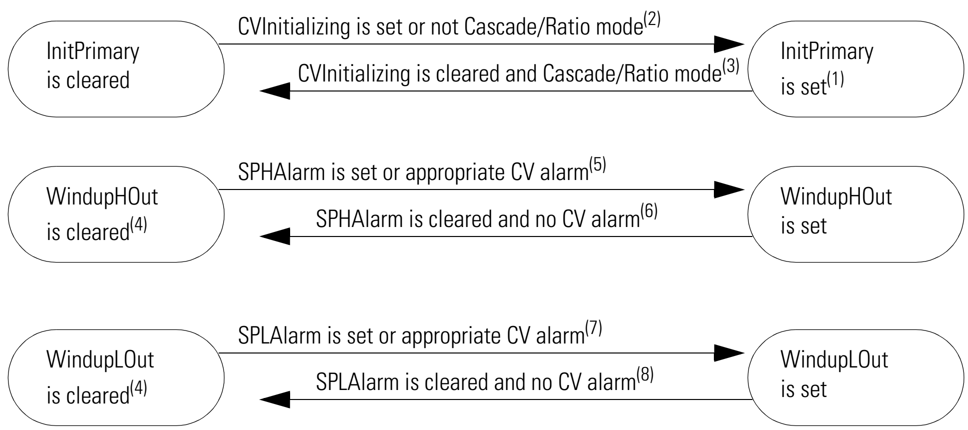
Updating the CVOper and CVProg values

If not in the Operator Manual mode, the PIDE instruction sets CVOper = CV. This obtains bumpless mode switching from any control to the Operator Manual mode.



Primary loop control

Primary loop control is typically used by a primary PID loop to obtain bumpless switching and anti-reset windup when using Cascade/Ratio mode. The primary loop control includes the initialize primary loop output and the anti-reset windup outputs. The InitPrimary output is typically used by the CVInitReq input of a primary PID loop. The windup outputs are typically used by the windup inputs of a primary loop to limit the windup of its CV output.



(1) During instruction first scan, the instruction sets InitPrimary.

(2) When CVInitializing is set or when not in Cascade/Ratio mode the instruction sets InitPrimary.

(3) When CVInitializing is cleared and in Cascade/Ratio mode, the instruction clears InitPrimary.

(4) During instruction first scan, the instruction clears the windup outputs. The instruction also clears the windup outputs and disables the CV windup algorithm when CVInitializing is set or if either CVFaulted or CVEUSpanInv is set.

(5) The instruction sets WindupHOut when SPHAlarm is set, or when ControlAction is cleared and CVHAlarm is set, or when ControlAction is set and CVLAlarm is set.

The SP and CV limits operate independently. A SP high limit does not prevent CV from increasing in value. Likewise, a CV high or low limit does not prevent SP from increasing in value.

(6) The instruction clears WindupHOut when SPHAlarm is cleared, and not (ControlAction is cleared and CVHAlarm is set), and not (ControlAction is set and CVLAlarm is set).

(7) The instruction sets WindupLOut when SPLAlarm is set, or when ControlAction is cleared and CVLAlarm is set, or when ControlAction is set and CVHAlarm is set.

The SP and CV limits operate independently. A SP low limit does not prevent CV from increasing in value. likewise a CV low or high limit does not prevent SP from increasing in value.

(8) The instruction clears WindupLOut when SPLAlarm is cleared and not (ControlAction is cleared and CVLAlarm is set) and not (ControlAction is set and CVHAlarm is set).

Processing faults

The following table describes how the instruction handles execution faults:

Fault condition:	Action:
CVFaulted is set **or** CVEUSpanInv is set	• Instruction is not initialized, CVInitializing is cleared • Compute PV and SP percent, calculate error, update internal parameters for EPercent and PVPIDPercent • PID control algorithm is not executed • Disable the Auto and Cascade/Ratio modes. If Override or Hand is not the current mode, set to Manual mode. • Set CV to value determined by Program or Operator control and mode (Manual, Override, or Hand).
PVFaulted is set	• Disable the Auto and Cascade/Ratio modes. If Override or Hand is not the current mode, set to Manual mode • PV high-low, PV rate-of-change, and deviation high-low alarm outputs are cleared • PID control algorithm is not executed • Set CV to value by determined by Program or Operator control and mode (Manual, Override, or Hand).
PVSpanInv is set **or** SPLimitsInv is set	• Disable the Auto and Cascade/Ratio modes. If Override or Hand is not the current mode, set to Manual mode • Do not compute PV and SP percent • PID control algorithm is not executed • Set CV to value by determined by Program or Operator control and mode (Manual, Override, or Hand).
RatioLimitsInv is set **and** CasRat is set **and** UseRatio is set	• If not already in Hand or Override, set to Manual model • Disable the Cascade/Ratio mode • Set CV to value determined by Program or Operator control and mode (Manual, Override, or Hand).
TimingModeInv is set **or** RTSTimeStampInv is set **or** DeltaTInv is set	• If not already in Hand or Override, set to Manual mode

Position Proportional (POSP)

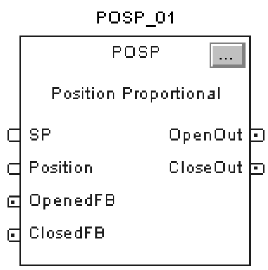
The POSP instruction opens or closes a device, such as a motor-operated valve, by pulsing open or close contacts at a user-defined cycle time with a pulse width proportional to the difference between the desired and actual positions.

Operands:

```
POSP(POSP_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
POSP tag	POSITION_PROP	structure	POSP structure



Function Block

Operand:	Type:	Format:	Description:
block tag	POSITION_PROP	structure	POSP structure

POSITION_PROP Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
SP	REAL	Setpoint. This is the desired value for the position. This value must use the same engineering units as Position. Valid = any float Default = 0.0
Position	REAL	Position feedback. This analog input comes from the position feedback from the device. Valid = any float Default = 0.0
OpenedFB	BOOL	Opened feedback. This input signals when the device is fully opened. When set, the open output is not allowed to turn on. Default is cleared.
ClosedFB	BOOL	Closed feedback. This input signals when the device is fully closed. When set, the close output is not allowed to turn on. Default is cleared.
PositionEUMax	REAL	Maximum scaled value of Position and SP. Valid = any float Default = 100.0

Input Parameter:	Data Type:	Description:
PositionEUMin	REAL	Minimum scaled value of Position and SP. Valid = any float Default = 0.0
CycleTime	REAL	Period of the output pulse in seconds. A value of zero clears both OpenOut and CloseOut. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = any positive float Default = 0.0
OpenRate	REAL	Open rate of the device in %/second. A value of zero clears OpenOut. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = any positive float Default = 0.0
CloseRate	REAL	Close rate of the device in %/second. A value of zero clears CloseOut. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = any positive float Default = 0.0
MaxOnTime	REAL	Maximum time in seconds that an open or close pulse can be on. If OpenTime or CloseTime is calculated to be larger than this value, they are limited to this value. If this value is invalid, the instruction assumes a value of CycleTime and sets the appropriate bit in Status. Valid = 0.0 to CycleTime Default = 0.0
MinOnTime	REAL	Minimum time in seconds that an open or close pulse can be on. If OpenTime or CloseTime is calculated to be less than this value, they are set to zero. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = 0.0 to MaxOnTime Default = 0.0
Deadtime	REAL	Additional pulse time in seconds to overcome friction in the device. Deadtime is added to the OpenTime or CloseTime when the device changes direction or is stopped. If this value is invalid, the instruction sets the appropriate bit in Status and uses a value of Deadtime = 0.0. Valid = 0.0 to MaxOnTime Default = 0.0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
OpenOut	BOOL	This output is pulsed to open the device.
CloseOut	BOOL	This output is pulsed to close the device.
PositionPercent	REAL	Position feedback is expressed as percent of the Position span. Arithmetic status flags are set for this output.
SPPercent	REAL	Setpoint is expressed as percent of the Position span.
OpenTime	REAL	Pulse time in seconds of OpenOutput for the current cycle.
CloseTime	REAL	Pulse time in seconds of CloseOutput for the current cycle.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
CycleTimeInv (Status.1)	BOOL	Invalid CycleTime value. The instruction uses zero.

Output Parameter:	Data Type:	Description:
OpenRateInv (Status.2)	BOOL	Invalid OpenRate value. The instruction uses zero.
CloseRateInv (Status.3)	BOOL	Invalid CloseRate value. The instruction uses zero.
MaxOnTimeInv (Status.4)	BOOL	Invalid MaxOnTime value. The instruction uses the CycleTime value.
MinOnTimeInv (Status.5)	BOOL	Invalid MinOnTime value. The instruction uses zero.
DeadtimeInv (Status.6)	BOOL	Invalid Deadtime value. The instruction uses zero.
PositionPctInv (Status.7)	BOOL	The calculated PositionPercent value is out of range.
SPPercentInv (Statius.8)	BOOL	The calculated SPPercent value is out of range.
PositionSpanInv (Status.9)	BOOL	PositionEUMax = PositionEUMin.

Description: The POSP instruction usually receives the desired position setpoint from a PID instruction output.

Scaling the position and set point values

The PositionPercent and SPPercent outputs are updated each time the instruction is executed. If either of these values is out of range (less than 0% or greater than 100%), the appropriate bit in Status is set, but the values are not limited. The instruction uses these formulas to calculate whether the values are in range:

$$PositionPercent = \frac{Position - PositionEUMin}{PositionEUMax - PositionEUMin} \times 100$$

$$SPPercent = \frac{SP - PositionEUMin}{PositionEUMax - PositionEUMin} \times 100$$

How the POSP instruction uses the internal cycle timer

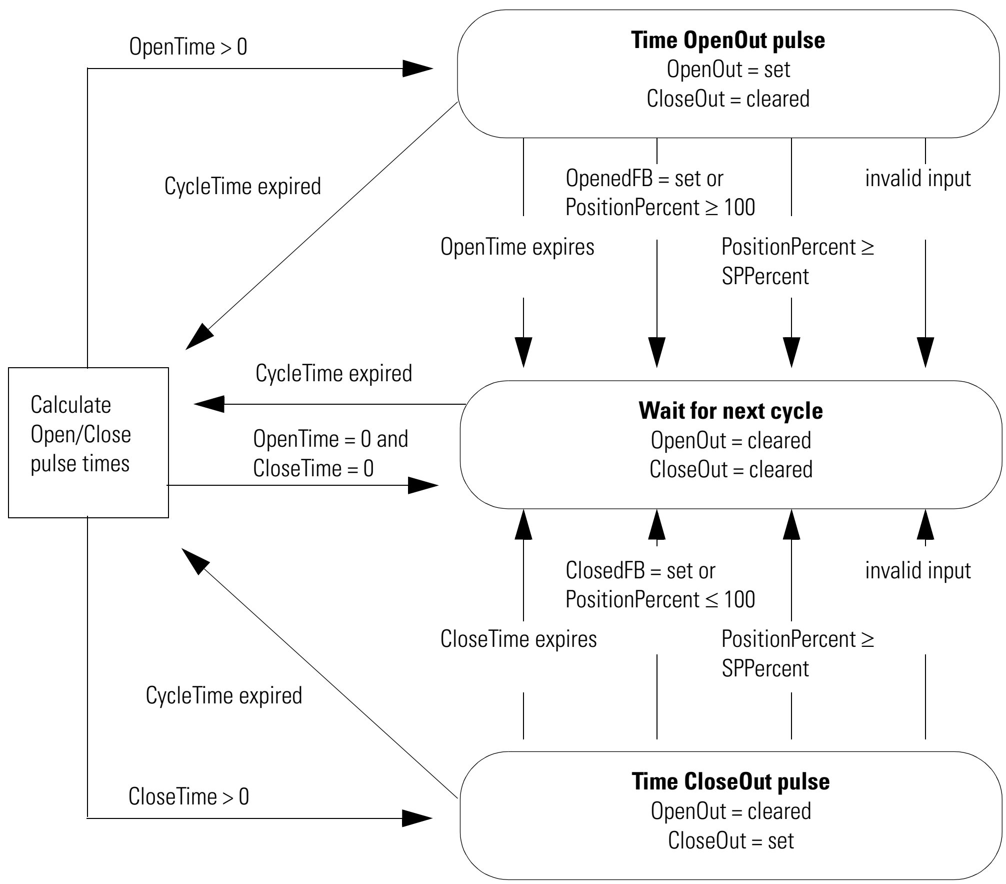
The instruction uses CycleTime to determine how often to recalculate the duration of Open and Close output pulses. An internal timer is maintained and updated by DeltaT. DeltaT is the elapsed time since the instruction last executed. Whenever the internal timer equals or exceeds the programmed CycleTime (cycle time expires) the Open and Close outputs are recalculated.

You can change the CycleTime at any time.

If CycleTime = 0, the internal timer is cleared, OpenOut is cleared, and CloseOut is cleared.

Producing output pulses

The following diagram shows the three primary states of the POSP instruction.



Calculating open and close pulse times

OpenOut is pulsed whenever SP > Position feedback. When this occurs, the instruction sets CloseTime = 0 and the duration for which OpenOut is to be turned on is calculated as:

$$OpenTime = \frac{SPPercent - PositionPercent}{OpenRate}$$

- If $OpenTime_{n-1}$ < CycleTime, then add Deadtime to OpenTime.
- If OpenTime > MaxOnTime, then limit to MaxOnTime.
- If OpenTime < MinOnTime, then set OpenTime = 0.

If any of the following conditions exist, OpenOut is not pulsed and OpenTime = 0.

- OpenFB is set or PositionPercent ≥ 100
- CycleTime = 0
- OpenRate = 0
- SPPercent is invalid

The CloseOut is pulsed whenever SP < Position feedback. When this occurs, the instruction sets OpenTime = 0 and the duration for which CloseOut is to be turned on is calculated as:

$$CloseTime = \frac{PositionPercent - SPPercent}{CloseRate}$$

- If $CloseTime_{n-1}$ < CycleTime, then add Deadtime to CloseTime.
- If CloseTime > MaxOnTime, then limit to MaxOnTime.
- If CloseTime < MinOnTime, then set CloseTime to 0.

If any of the following conditions exist, CloseOut will not be pulsed and CloseTime will be cleared.

- ClosedFB is set or PositionPercent ≤ 0
- CycleTime = 0
- CloseRate = 0
- SPPercent is invalid

OpenOut and CloseOut will not be pulsed if SPPercent equals PositionPercent. Both OpenTime and CloseTime will be cleared.

Arithmetic Status Flags: Arithmetic status flags are set for the PositionPercent output.

Fault Conditions: none

Execution:

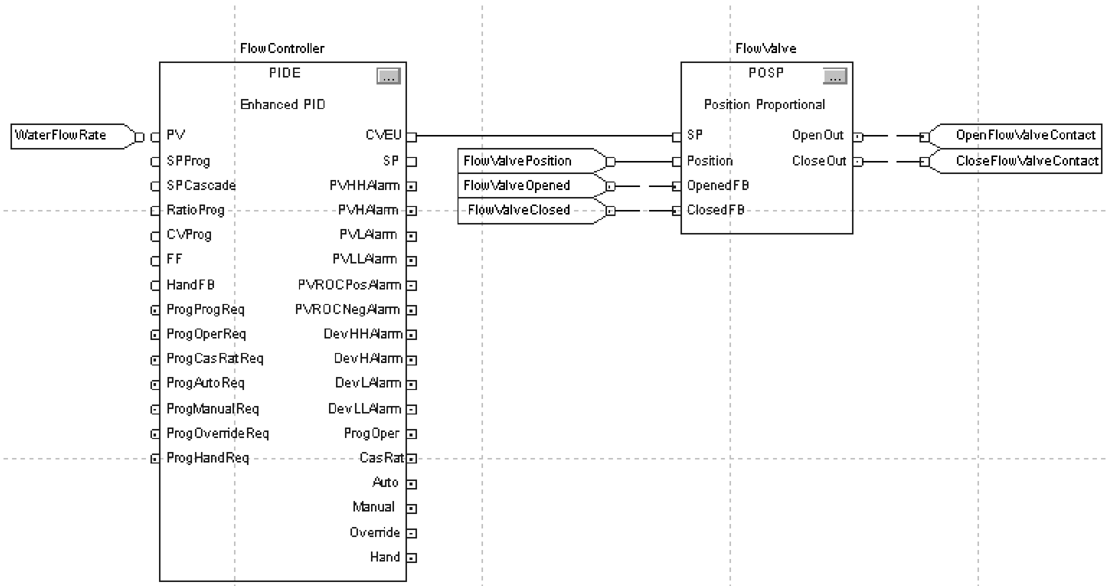
Condition:	Function Block Action:	Structured Text Action:
prescan	OpenOut and CloseOut are cleared. OpenTime = 0 CloseTime = 0.	OpenOut and CloseOut are cleared. OpenTime = 0 CloseTime = 0.
instruction first scan	The internal cycle timer is reset. The instruction calculates OpenTime and Close Time.	The internal cycle timer is reset. The instruction calculates OpenTime and Close Time.
instruction first run	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: In this example, the POSP instruction opens or closes a motor-operated valve based on the CVEU output of the PIDE instruction. The actual valve position is wired into the Position input and optional limit switches, which show if the valve is fully opened or closed, are wired into the OpenedFB and ClosedFB inputs. The OpenOut and CloseOut outputs are wired to the open and close contacts on the motor-operated valve.

Structured Text

```
FlowController.PV := WaterFlowRate;
PIDE(FlowController);

FlowValve.SP := FlowController.CVEU;
FlowValve.Position := FlowValvePosition;
FlowValve.OpenedFB := FlowValveOpened;
FlowValve.ClosedFB := FlowValveClosed;
POSP(FlowValve);

OpenFlowValveContact := FlowValve.OpenOut;
CloseFlowValveContact := FlowValve.CloseOut;
```

Function Block



Ramp/Soak (RMPS)

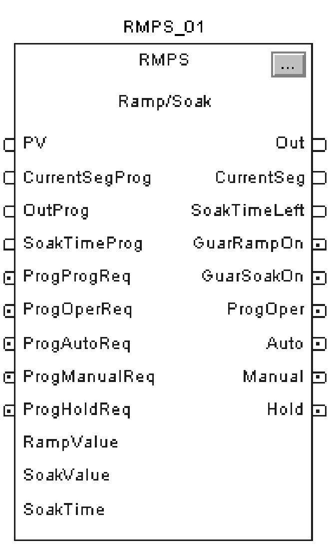
The RMPS instruction provides for a number of segments of alternating ramp and soak periods.

Operands:

```
RMPS(RMPS_tag,RampValue,
     SoakValue,SoakTime);
```

Structured Text

Operand:	Type:	Format:	Description:
RMPS tag	RAMP_ SOAK	structure	RMPS structure
RampValue	REAL	array	Ramp Value array. Enter a ramp value for each segment (0 to NumberOfSegs-1). Ramp values are entered as time in minutes or as a rate in units/minute. The TimeRate parameter reflects which method is used to specify the ramp. If a ramp value is invalid, the instruction sets the appropriate bit in Status and changes to Operator Manual or Program Hold mode. The array must be at least as large as NumberOfSegs. valid = 0.0 to maximum positive float
SoakValue	REAL	array	Soak Value array. Enter a soak value for each segment (0 to NumberOfSegs-1). The array must be at least as large as NumberOfSegs. valid = any float
SoakTime	REAL	array	Soak Time array. Enter a soak time for each segment (0 to NumberOfSegs-1). Soak times are entered in minutes. If a soak value is invalid, the instruction sets the appropriate bit in Status and changes to Operator Manual or Program Hold mode. The array must be at least as large as NumberOfSegs. valid = 0.0 to maximum positive float



Function Block

The operands are the same as for the structured text RMPS instruction.

RAMP_SOAK Structure:

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
PV	REAL	The scaled analog temperature signal input to the instruction. Valid = any float Default = 0.0
PVFault	BOOL	Bad health indicator of PV. If set, the input is invalid, the instruction is placed in Program Hold or Operator Manual mode, and the instruction sets the appropriate bit in Status. Default is cleared.
NumberOfSegs	DINT	Number of segments. Specify the number of ramp/soak segments used by the instruction. The arrays for RampValue, SoakValue, and SoakTime must be at least as large as NumberOfSegs. If this value is invalid, the instruction is placed into Operator Manual or Program Hold mode and the instruction sets the appropriate bit in Status. Valid = 1 to (minimum size of RampValue, SoakValue, or SoakTime arrays) Default = 1
ManHoldAftInit	BOOL	Manual/Hold after initialization. If set, the ramp/soak is in Operator Manual or Program Hold mode after initialization completes. Otherwise, the ramp/soak remains is in its previous mode after initialization completes. Default is cleared.
CyclicSingle	BOOL	Cyclic/single execution. Set for cyclic action or clear for single action. Cyclic action continuously repeats the ramp/soak profile. Single action performs the ramp/soak profile once and then stops. Default is cleared.
TimeRate	BOOL	Time/rate ramp value configuration. Set if the RampValue parameters are entered as a time in minutes to reach the soak temperature. Clear if the RampValue parameters are entered as a rate in units/minute. Default is cleared.
GuarRamp	BOOL	Guaranteed ramp. If set and the instruction is in auto, ramping is temporarily suspended if the PV differs from the Output by more than RampDeadband. Default is cleared.
RampDeadband	REAL	Guaranteed ramp deadband. Specify the amount in engineering units that PV is allowed to differ from the output when GuarRamp is on. If this value is invalid, the instruction sets RampDeadband = 0.0 and the instruction sets the appropriate bit in Status. Valid = any float ≥ 0.0 Default = 0.0
GuarSoak	BOOL	Guaranteed soak. If set and the instruction is in auto, the soak timer is cleared if the PV differs from the Output by more than SoakDeadband. Default is cleared.
SoakDeadband	REAL	Guaranteed soak deadband. Specify the amount in engineering units that the PV is allowed to differ from the output when GuarSoak is on. If this value is invalid, the instruction sets SoakDeadband = 0.0 and the instruction sets the appropriate bit in Status. Valid = any float ≥ 0.0 Default = 0.0

Input Parameter:	Data Type:	Description:
CurrentSegProg	DINT	Current segment program. The user program writes a requested value for the CurrentSeg into this input. This value is used if the ramp/soak is in Program Manual mode. If this value is invalid, the instruction sets the appropriate bit in Status. Valid = 0 to NumberOfSegs-1 Default = 0
OutProg	REAL	Output program. The user program writes a requested value for the Out into this input. This value is used as the Out when the ramp/soak is in Program Manual mode. Valid = any float Default = 0.0
SoakTimeProg	REAL	Soak time program. The user program writes a requested value for the SoakTimeLeft into this input. This value is used if the ramp/soak is in Program Manual mode. If this value is invalid, the instruction sets the appropriate bit in Status. Valid = 0.0 to maximum positive float Default = 0.0
CurrentSegOper	DINT	Current segment operator. The operator interface writes a requested value for the CurrentSeg into this input. This value is used if the ramp/soak is in Operator Manual mode. If this value is invalid, the instruction sets the appropriate bit in Status. Valid = 0 to NumberOfSegs-1 Default = 0
OutOper	REAL	Output operator. The operator interface writes a requested value for the Out into this input. This value is used as the Out when the ramp/soak is in Operator Manual mode. Valid = any float Default = 0.0
SoakTimeOper	REAL	Soak time operator. The operator interface writes a requested value for the SoakTimeLeft into this input. This value is used if the ramp/soak is in Operator Manual mode. If this value is invalid, the instruction sets the appropriate bit in Status. Valid = 0.0 to maximum positive float Default = 0.0
ProgProgReq	BOOL	Program program request. Set by the user program to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction in Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set by the user program to request Operator control. Holding this set locks the instruction in Operator control. Default is cleared.
ProgAutoReq	BOOL	Program auto mode request. Set by the user program to request the ramp/soak to enter Auto mode. Ignored if the loop is in Operator control, if ProgManualReq is set, or if ProgHoldReq is set. Default is cleared.
ProgManualReq	BOOL	Program manual mode request. Set by the user program to request the ramp/soak to enter Manual mode. Ignored if the ramp/soak is in Operator control or if ProgHoldReq is set. Default is cleared.
ProgHoldReq	BOOL	Program hold mode request. Set by the user program to request to stop the ramp/soak without changing the Out, CurrentSeg, or SoakTimeLeft. Also useful when a PID loop getting its setpoint from the ramp/soak leaves cascade. An operator can accomplish the same thing by placing the ramp/soak into Operator Manual mode. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. Ignored if ProgOperReq is set. The instruction clears this input. Default is cleared.

Input Parameter:	Data Type:	Description:
OperOperReq	BOOL	Operator operator request. Set by the operator interface to request Operator control. Ignored if ProgProgReq is set and ProgOperReq is cleared. The instruction clears this input. Default is cleared.
OperAutoReq	BOOL	Operator auto mode request. Set by the operator interface to request the ramp/soak to enter Auto mode. Ignored if the loop is in Program control or if OperManualReq is set. The instruction clears this input. Default is cleared.
OperManualReq	BOOL	Operator manual mode request. Set by the operator interface to request the ramp/soak to enter Manual mode. Ignored if the loop is in Program control. The instruction clears this input. Default is cleared.
Initialize	BOOL	Initialize program and operator values. When set and in manual, the instruction sets CurrentSegProg = 0, CurrentSegOper = 0, SoakTimeProg = SoakTime[0], and SoakTimeOper = SoakTime[0]. Initialize is ignored when in Auto or Hold mode. The instruction clears this parameter. Default is cleared.
ProgValueReset	BOOL	Reset program control values. When set, the instruction clears ProgProgReq, ProgOperReq, ProgAutoReq, ProgHoldReq, and ProgManualReq. Default is cleared.

Input Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The output of the ramp/soak instruction. Arithmetic status flags are used for this output.
CurrentSeg	DINT	Current segment number. Displays the current segment number in the ramp/soak cycle. Segments start numbering at 0.
SoakTimeLeft	REAL	Soak time left. Displays the soak time remaining for the current soak.
GuarRampOn	BOOL	Guaranteed ramp status. Set if the Guaranteed Ramp feature is in use and the ramp is temporarily suspended because the PV differs from the output by more than the RampDeadband.
GuarSoakOn	BOOL	Guaranteed soak status. Set if the Guaranteed Soak feature is in use and the soak timer is cleared because the PV differs from the output by more than the SoakDeadband.
ProgOper	BOOL	Program/Operator control indicator. Set when in Program control. Cleared when in Operator control.
Auto	BOOL	Auto mode. Set when the ramp/soak is in Program Auto or Operator Auto mode.
Manual	BOOL	Manual mode. Set when the ramp/soak is in Program Manual or Operator Manual mode.
Hold	BOOL	Hold mode. Set when the ramp/soak is in program Hold mode.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
PVFaulted (Status.1)	BOOL	PVHealth is bad.
NumberOfSegsInv (Status.2)	BOOL	The NumberOfSegs value is invalid value or is not compatible with an array size.
RampDeadbandInv (Status.3)	BOOL	Invalid RampDeadband value.

Input Parameter:	Data Type:	Description:
SoakDeadbandInv (Status.4)	BOOL	Invalid SoakDeadband value.
CurrSegProgInv (Status.5)	BOOL	Invalid CurrSegProg value.
SoakTimeProgInv (Status.6)	BOOL	Invalid SoakTimeProg value.
CurrSegOperInv (Status.7)	BOOL	Invalid CurrSegOper value.
SoakTimeOperInv (Status.8)	BOOL	Invalid SoakTimeOper value.
RampValueInv (Status.9)	BOOL	Invalid RampValue value.
SoakTimeInv (Status.10)	BOOL	Invalid SoakTime value.

Description: The RMPS instruction is typically used to provide a temperature profile in a batch heating process. The output of this instruction is typically the input to the setpoint of a PID loop.

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. The internal parameters are not updated. In each subsequent scan, the output is computed using the internal parameters from the last scan when the output was valid.

Monitoring the RMPS instruction

There is an operator faceplate available for the RMPS instruction. For more information, see appendix Function Block Faceplate Controls.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	All the operator request inputs are cleared. If ProgValueReset is set, all the program request inputs are cleared. The operator control mode is set to manual mode if the current mode is hold. See the tables below.	
instruction first run	CurrentSegment = 0. SoakTimeProg and SoakTimeOper = SoakTime[0] if SoakTime[0] is valid. Mode is set to operator manual. Out_{n-1} = 0.0.	
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Initial mode applied on instruction first scan

The following table shows the ending control based on the program request inputs.

Control at Start of First Scan:	Prog Oper Req:	Prog Prog Req:	Prog Value Reset:	First Run:	Control at End of First Scan:
Operator control	cleared	set	cleared	na	Program control
	na	cleared	na	na	Operator control
Program control	set	na	cleared	cleared	Operator control
	na	na	set	set	
	cleared	cleared	cleared	set	
	cleared	set	cleared	na	
	na	na	set	cleared	
	cleared	cleared	cleared	cleared	

The following table shows the ending control based on the Manual, Auto, and Hold mode requests.

Control at Start of First Scan:	Oper Auto Req:	Oper Man Req:	Prog Auto Req:	Prog Man Req:	Prog Hold Req:	Manual Hold After Init:	Prog Value Reset:	First Run	Control at End of First Scan:
Operator control	na	na	na	na	na	cleared	na	cleared	Operator current mode
	na	na	na	na	na	na	na	set	Operator Manual mode
	na	na	na	na	na	set	na	na	
Program control	na	na	cleared	cleared	cleared	cleared	na	cleared	Program current mode
	na	na	na	na	na	cleared	set	cleared	
	na	na	set	cleared	cleared	cleared	cleared	na	Program Auto mode
	na	na	na	set	cleared	cleared	cleared	na	Program Manual mode
	na	na	na	na	set	cleared	cleared	na	Program Hold mode
	na	na	na	na	na	set	na	na	

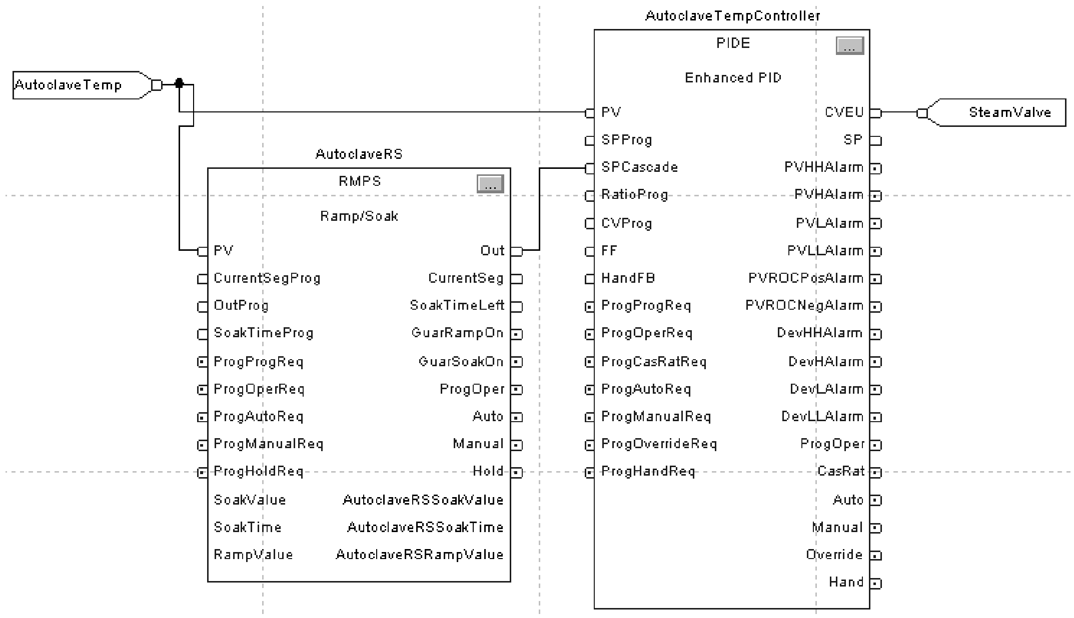
Example: In this example, the RMPS instruction drives the setpoint of a PIDE instruction. When the PIDE instruction is in Cascade/Ratio mode, the output of the RMPS instruction is used as the setpoint. The PV to the PIDE instruction can be optionally fed into the PV input of the RMPS instruction if you want to use guaranteed ramping and/or guaranteed soaking.

In this example, the AutoclaveRSSoakValue, AutoclaveRSSoakTime, and AutoclaveRSRampValue arrays are REAL arrays with 10 elements to allow up to a 10 segment RMPS profile.

Structured Text

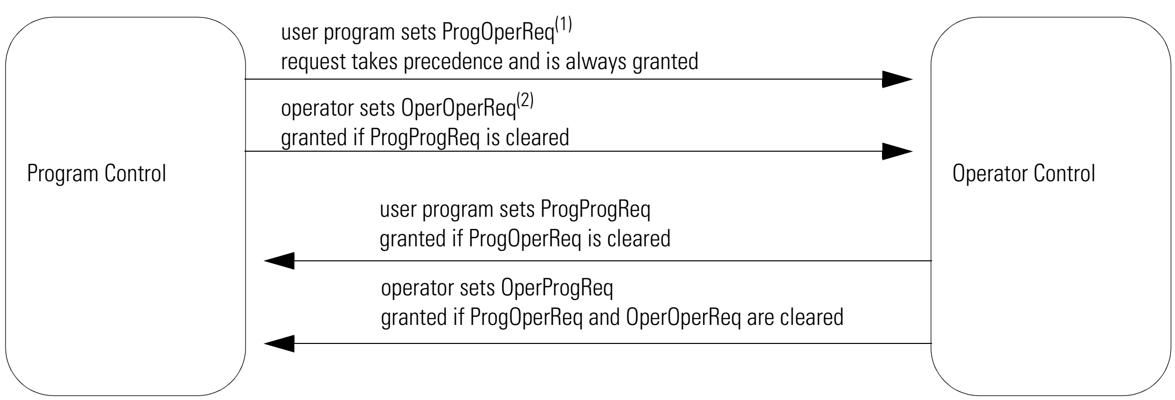
```
AutoclaveRS.PV := AutoclaveTemp;
RMPS (AutoclaveRS,AutoclaveRSRampValue,
    AutoclaveRSSoakValue,AutoclaveRSSoakTime);

AutoclaveTempController.PV := AutoclaveTemp;
AutoclaveTempController.SPCascade := AutoclaveRS.Out;
PIDE(AutoclaveTempController);

SteamValve := AutoclaveTempController.CVEU;
```

Function Block



Switching between Program control and Operator control

The RMPS instruction can be controlled by either a user program or through an operator interface. Control can be changed any time.



(1) You can lock the instruction in Operator control by leaving ProgOperReq set.

(2) You can lock the instruction in Program control by leaving ProgProgReq set while ProgOperReq is cleared

For more information on program and operator control, see page B-13.

When transitioning from Operator control to Program control while the ProgAutoReq, ProgManualReq, and ProgHoldReq inputs are cleared, the mode is determined as follows:

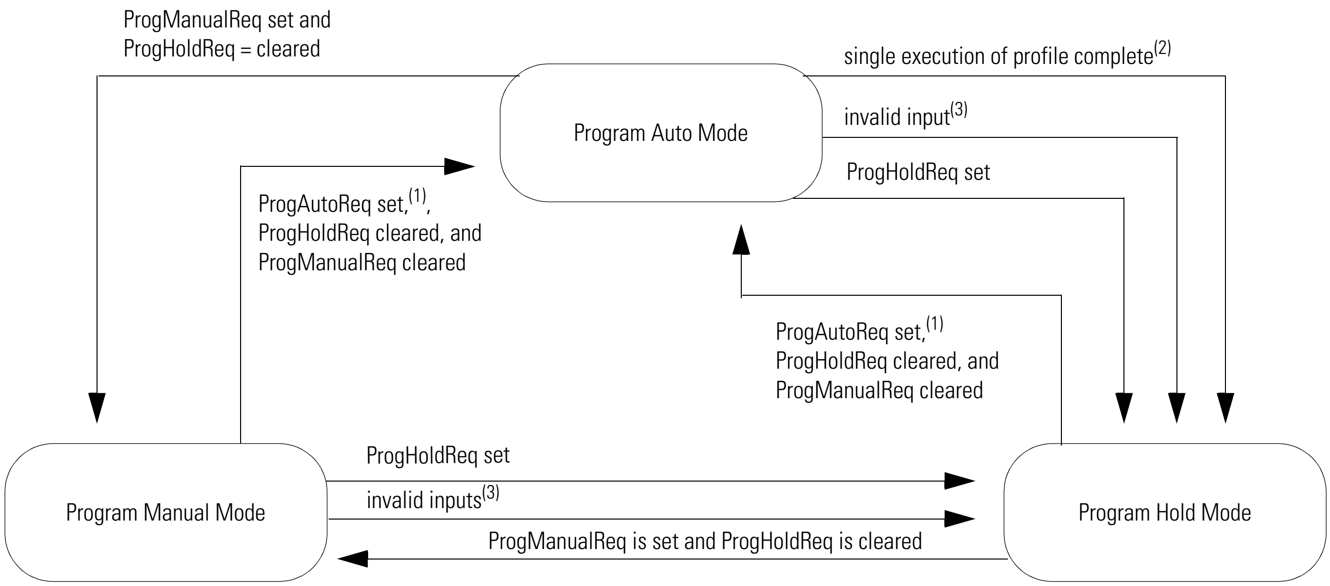
- If the instruction was in Operator Auto mode, then the transition is to Program Auto mode.
- If the instruction was in Operator Manual mode, then the transition is to Program Manual mode.

When transitioning from Program control to Operator control while the OperAutoReq and OperManualReq inputs are cleared, the mode is determined as follows:

- If the instruction was in Program Auto mode, then the transition is to Operator Auto mode.
- If the instruction was in Program Manual or Program Hold mode, then the transition is to Operator Manual mode.

Program control

The following diagram illustrates how the RMPS instruction operates in Program control.



(1) In single (non-cyclic) execution, you must toggle ProgAutoReq from cleared to set if one execution of the ramp/soak profile is complete and you want another execution of the ramp/soak profile.

(2) When the instruction is configured for single execution, and the Auto mode Ramp-Soak profile completes, the instruction transitions to Hold mode.

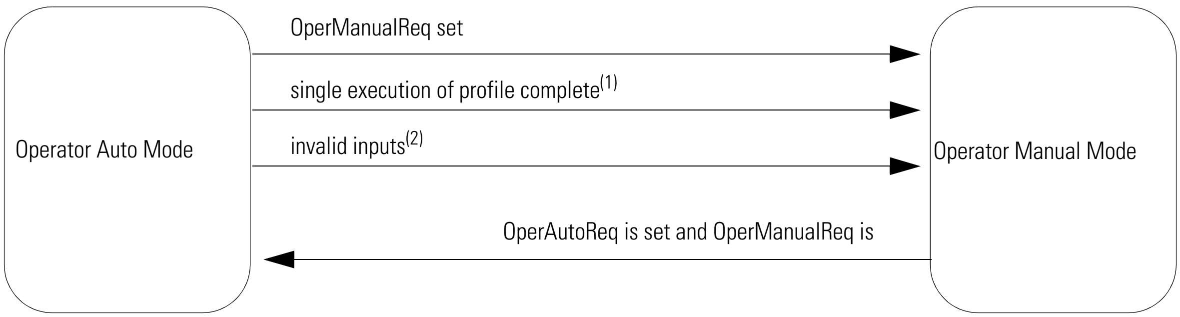
(3) The instruction is placed in Hold mode if PVFaulted is set or any of the following inputs are invalid: NumberOfSegs, CurrentSeg, SoakTimeLeft, CurrentSegProg, or SoakTimeProg.

The following table describes the possible Program modes.

Mode:	Description:
Program Auto Mode	While in Auto mode, the instruction sequentially executes the ramp/soak profile.
Program Manual Mode	While in Manual mode the user program directly controls the instruction's Out. The CurrentSegProg, SoakTimeProg, and OutProg inputs are transferred to the CurrentSeg, SoakTimeLeft, and Out outputs. When the instruction is placed in auto mode, the ramp/soak function resumes with the values last input from the user program. CurrentSegProg and SoakTimeProg are not transferred if they are invalid. To facilitate a "bumpless" transition into Manual mode, the CurrentSegProg, SoakTimeProg, and OutProg inputs are continuously updated to the current values of CurrentSeg, SoakTimeLeft, and Out when ProgValueReset is set and the instruction is not in Program Manual mode.
Program Hold Mode	While in Hold mode, the instruction's outputs are maintained at their current values. If in this mode when ProgOperReq is set to change to Operator control, the instruction changes to Operator Manual mode.

Operator control

The following diagram illustrates how the RMPS instruction operates in Operator control.



(1) When the instruction is configured for Single Execution, and the Auto mode ramp/soak profile completes, the instruction transitions to manual mode.

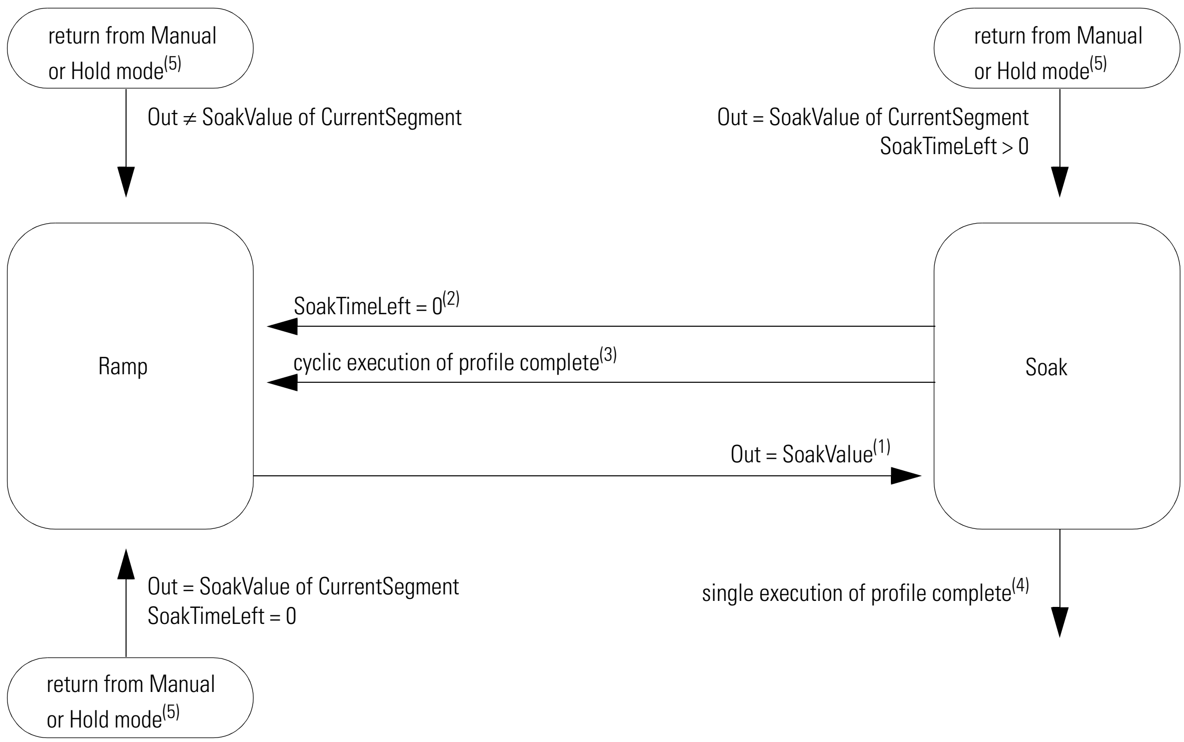
(2) The instruction is placed in Manual mode if PVFaulted is set or any of the following inputs are invalid: NumberOfSegs, CurrentSeg, SoakTimeLeft, CurrentSegOper, or SoakTimeOper.

The following table describes the possible Operator modes

Mode:	Description:
Operator Auto Mode	While in Auto mode, the instruction sequentially executes the ramp/soak profile
Operator Manual Mode	While in Manual mode the operator directly controls the instruction's Out. The CurrentSegOper, SoakTimeOper, and OutOper inputs are transferred to the CurrentSeg, SoakTimeLeft, and Out outputs. When the instruction is placed in Auto mode, the ramp/soak function resumes with the values last input from the operator. CurrentSegOper and SoakTime are not transferred if they are invalid. To facilitate a "bumpless" transition into Manual mode, the CurrentSegOper, SoakTimeOper, and OutOper inputs are continuously updated to the current values of CurrentSeg, SoakTimeLeft, and Out whenever the instruction is not in Operator Manual mode.

Executing the ramp/soak profile

The following diagram illustrates how the RMPS instruction executes the ramp/soak profile.



(1) The Ramp is complete when Out = SoakValue. If, during ramp execution, Out > SoakValue, Out is limited to SoakValue.

(2) Soaking is complete when Out is held for the amount of time specified in the current segment's SoakTime. If the segment executed was not the last segment, CurrentSeg increments by one.

(3) Soaking has completed for the last programmed segment and the instruction is configured for cyclic execution. The instruction sets CurrentSeg = 0.0.

(4) Soaking has completed for the last programmed segment and the instruction is configured for single execution.

(5) When returning to Auto mode, the instruction determines if ramping or soaking resumes. What to do next depends on the values of Out, SoakTimeLeft, and the SoakValue of the current segment. If Out = SoakValue for the current segment, and SoakTimeLeft = 0, then the current segment has completed and the next segment starts.

Ramping

The ramp cycle ramps Out from the previous segment's SoakValue to the current segment's SoakValue. The time in which the ramp is traversed is defined by the RampValue parameters.

Ramping is positive if Out < target SoakValue of the current segment. If the ramp equation calculates a new Out which exceeds the target SoakValue, the Out is set to the target SoakValue.

Ramping is negative if Out > the target SoakValue of the current segment. If the ramp equation calculates a new Out which is less then the target SoakValue, the Out is set to the target SoakValue.

Each segment has a ramp value. You have the option of programming the ramp in units of time or rate. All segments must be programmed in the same units. The following table describes the ramping options:

Parameter:	Description:
time-based ramping	TimeRate is set for time-based ramping (in minutes) The rate of change for the current segment is calculated and either added or subtracted to Out until Out reaches the current segment's soak value. In the following equation DeltaT is the elapsed time in minutes since the instruction last executed. $Out = Out \pm \frac{(SoakValue_{CurrentSeg} - RampStart)}{RampValue_{CurrentSeg}} \times \Delta t$ Where RampStart is the value of Out at the start of the Current Segment.
rate-based ramping	TimeRate is cleared for rate-based ramping (in units/minute) The programmed rate of change is either added or subtracted to Out until Out reaches the current segment's soak value. In the following equation DeltaT is the elapsed time in minutes since the instruction last executed. $Out = Out \pm RampValue_{CurrentSeg} \times \Delta t$

Guaranteed ramping

Set the input GuarRamp to enable guaranteed ramping. When enabled, the instruction monitors the difference between Out and PV. If the difference is outside of the programmed RampDeadband, the output is left unchanged until the difference between PV and Out are within the deadband. The output GuarRampOn is set whenever Out is held due to guaranteed ramping being in effect.

Soaking

Soaking is the amount of time the block output is to remain unchanged until the next ramp-soak segment is started. The soak cycle holds the output at the SoakValue for a programmed amount of time before proceeding to the next segment. The amount of time the output is to soak is programmed in the SoakTime parameters.

Each segment has a SoakValue and SoakTime. Soaking begins when Out is ramped to the current segment's SoakValue. SoakTimeLeft represents the time in minutes remaining for the output to soak. During ramping, SoakTimeLeft is set to the current segment's SoakTime. Once ramping is complete, SoakTimeLeft is decreased to reflect the time in minutes remaining for the current segment. SoakTimeLeft = 0 when SoakTime expires.

Guaranteed soaking

Set the input GuarSoak to enable guaranteed soaking. When enabled, the instruction monitors the difference between Out and PV. If the difference is outside of the SoakDeadband, timing of the soak cycle is suspended and the internal soak timer is cleared. When the difference between Out and PV returns to within the deadband, timing resumes. The output GuarSoak is set when timing is held due to guaranteed soaking being in effect.

Scale (SCL)

The SCL instruction converts an unscaled input value to a floating point value in engineering units.

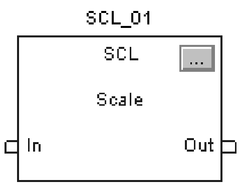
Operands:

Structured Text

```
SCL(SCL_tag);
```

Operand:	Type:	Format:	Description:
SCL tag	SCALE	structure	SCL structure

Function Block



Operand:	Type:	Format:	Description:
SCL tag	SCALE	structure	SCL structure

SCALE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input. Valid = any real value Default = 0.0
InRawMax	REAL	The maximum value attainable by the input to the instruction. If InRawMax ≤ InRawMin, the instruction sets the appropriate bit in Status and stops updating the output. Valid = InRawMax > InRawMin Default = 0.0
InRawMin	REAL	The minimum value attainable by the input to the instruction. If InRawMin ≥ InRawMax, the instruction sets the appropriate bit in Status and stops updating the output. Valid = InRawMin < InRawMax Default = 0.0
InEUMax	REAL	The scaled value of the input corresponding to InRawMax. Valid = any real value Default = 0.0
InEUMin	REAL	The scaled value of the input corresponding to InRawMin. Valid = any real value Default = 0.0
Limiting	BOOL	Limiting selector. If set, Out is limited to between InEUMin and InEUMax. Default is cleared.

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The output that represents scaled value of the analog input. Arithmetic status flags are set for this output. valid = any real value default = InEUMin
MaxAlarm	BOOL	The above maximum input alarm indicator. This value is set when In> InRawMax.
MinAlarm	BOOL	The below minimum input alarm indicator. This value is set when In < InRawMin.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
InRawRangeInv (Status.1)	BOOL	InRawMin ≥ InRawMax.

Description:

Use the SCL instruction with analog input modules that do not support scaling to a full resolution floating point value.

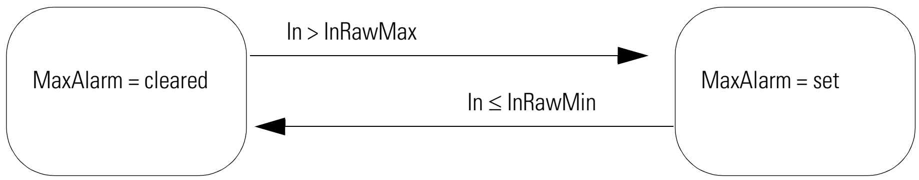
For example, the 1771-IFE module is a 12-bit analog input module that supports scaling only in integer values. If you use a 1771-IFE module to read a flow of 0-100 gallons per minute (gpm), you typically do not scale the module from 0-100 because that limits the resolution of the module. Instead, use the SCL instruction and configure the module to return an unscaled (0-4095) value, which the SCL instruction converts to 0-100 gpm (floating point) without a loss of resolution. This scaled value could then be used as an input to other instructions.

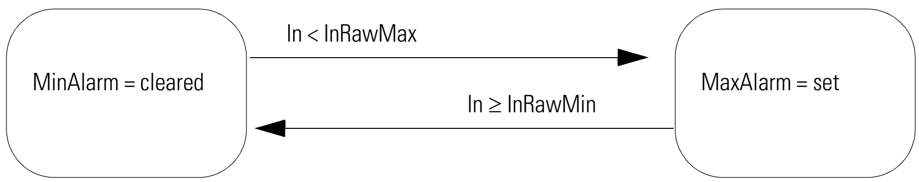
The SCL instruction uses this algorithm to convert unscaled input into a scaled value:

$$Out = (In - InRawMin) \times \left(\frac{InEUMax - InEUMin}{InRawMax - InRawMin}\right) + InEUMin$$

Alarming

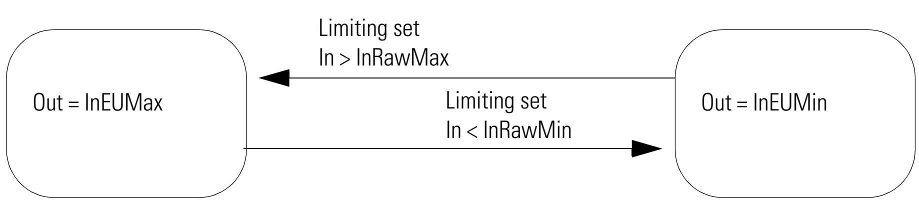
Once the instruction calculates Out, the MaxAlarm and MinAlarm are determined as follows:





Limiting

Limiting is performed on Out when Limiting is set. The instruction sets Out = InEUMax when In > InRawMax. The instruction sets Out = InEUMin when In < InRawMin.



Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

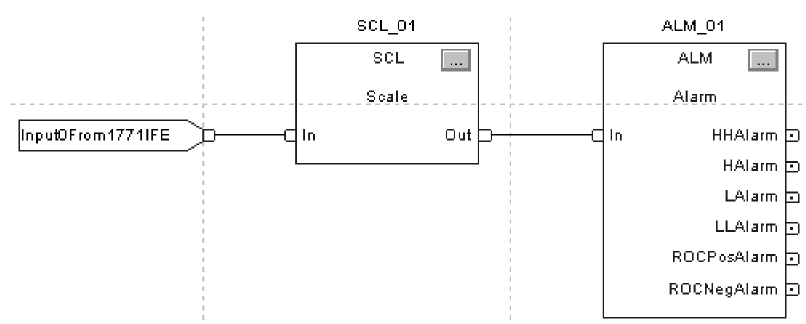
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The SCL instruction is typically used with analog input modules that do not support on-board scaling to floating point engineering units. In this example, the SCL instruction scales an analog input from a 1771-IFE module. The instruction places the result in Out, which is used by an ALM instruction.

Structured Text

```
SCL_01.In := Input0From1771IFE;
SCL(SCL_01);

ALM_01.In := SCL_01.Out;
ALM(ALM_01);
```

Function Block



Split Range Time Proportional (SRTP)

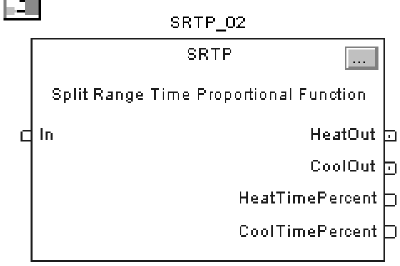
The SRTP instruction takes the 0-100% output of a PID loop and drives heating and cooling digital output contacts with a periodic pulse. This instruction controls applications such as barrel temperature control on extrusion machines.

Operands:

```
SRTP(SRTP_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
SRTP tag	SPLIT_RANGE	structure	SRTP structure



Function Block

Operand:	Type:	Format:	Description:
SRTP tag	SPLIT_RANGE	structure	SRTP structure

SPLIT_RANGE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input asking for heating or cooling. This input typically comes from the CVEU of a PID loop. Valid = any float
CycleTime	REAL	The period of the output pulses in seconds. A value of zero turns off both heat and cool outputs. If this value is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = any positive float Default = 0.0
MaxHeatIn	REAL	Maximum heat input. This value specifies the percentage of the In which will cause maximum heating. This is typically 100% for a heat/cool loop. Valid = any float Default = 100.0
MinHeatIn	REAL	Minimum heat input. Specify the percent of In that represents the start of the heating range and causes minimum heating. This is typically 50% for a heat/cool loop. Valid = any float Default = 50.0

Input Parameter:	Data Type:	Description:
MaxCoolIn	REAL	Maximum cool input. Specify the percent of In that causes maximum cooling. This is typically 0% for a heat/cool loop. Valid = any float Default = 0.0
MinCoolIn	REAL	Minimum cool input. Specify the percent of In that causes minimum cooling. This is typically 50% for a heat/cool loop. Valid = any float Default = 50.0
MaxHeatTime	REAL	Maximum heat time in seconds. Specify the maximum time in seconds that a heating pulse can be on. If the instruction calculates HeatTime to be greater than this value, HeatTime is limited to MaxHeatTime. If MaxHeatTime is invalid, the instruction assumes a value of CycleTime and sets the appropriate bit in Status. Valid = 0.0 to CycleTime Default = 0.0
MinHeatTime	REAL	Minimum heat time in seconds. Specify the minimum time in seconds that a heating pulse can be on. If the instruction calculates HeatTime to be less than this value, HeatTime is set to zero. If MinHeatTime is invalid, the instruction assumes a value of zero and sets the appropriate bit in Status. Valid = 0.0 to MaxHeatTime Default = 0.0
MaxCoolTime	REAL	Maximum cool time in seconds. Specify the maximum time in seconds that a cooling pulse can be on. If the instruction calculates CoolTime to be larger than this value, CoolTime is limited to MaxCoolTime. If MaxCoolTime is invalid, the instruction assumes a value of CycleTime and sets the appropriate bit in Status. Valid = 0.0 to CycleTime Default = 0.0
MinCoolTime	REAL	Minimum cool time in seconds. Specify the minimum time in seconds that a cooling pulse can be on. If the instruction calculates CoolTime to be less than this value, CoolTime is set to zero. If MinCoolTime is invalid, the instructions assumes a value of zero and sets the appropriate bit in Status. Valid = 0.0 to MaxCoolTime Default = 0.0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
HeatOut	BOOL	Heating output pulse. The instruction pulses this output for the heating contact.
CoolOut	BOOL	Cooling output pulse. The instruction pulses this output for the cooling contact.
HeatTimePercent	REAL	Heating output pulse time in percent. This value is the calculated percent of the current cycle that the HeatingOutput will be on. This allows you to use the instruction with an analog output for heating if required. Arithmetic status flags are set for this output.
CoolTimePercent	REAL	Cooling output pulse time in percent. This value is the calculated percent of the current cycle that the CoolingOutput will be on. This allows you to use the instruction with an analog output for cooling if required. Arithmetic status flags are set for this output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.

Output Parameter:	Data Type:	Description:
CycleTimeInv (Status.1)	BOOL	Invalid CycleTime value. The instruction uses zero.
MaxHeatTimeInv (Status.2)	BOOL	Invalid MaxHeatTime value. The instruction uses the CycleTime value.
MinHeatTimeInv (Status.3)	BOOL	Invalid MinHeatTime value. The instruction uses zero.
MaxCoolTimeInv (Status.4)	BOOL	Invalid MaxCoolTime value. The instruction uses the CycleTime value.
MinCoolTimeInv (Status.5)	BOOL	Invalid MinCoolTime value. The instruction uses zero.
HeatSpanInv (Status.6)	BOOL	MaxHeatIn = MinHeatIn.
CoolSpanInv (Status.7)	BOOL	MaxCoolIn = MinCoolIn.

Description: The length of the SRTP pulse is proportional to the PID output. The instruction parameters accommodate heating and cooling applications.

Using the internal cycle timer

The instruction maintains a free running cycle timer that cycles from zero to the programmed CycleTime. The internal timer is updated by DeltaT. DeltaT is the elapsed time since the instruction last executed. This timer determines if the outputs need to be turned on.

You can change CycleTime at any time. If CycleTime = 0, the internal timer is cleared and HeatOut and CoolOut are cleared.

Calculating heat and cool times

Heat and cool times are calculated every time the instruction is executed.

HeatTime is the amount of time within CycleTime that the heat output is to be turned on.

$$HeatTime = \frac{In - MinHeatIn}{MaxHeatIn - MinHeatIn} \times CycleTime$$

- If HeatTime < MinHeatTime, set HeatTime = 0.
- If HeatTime> MaxHeatTime, limit HeatTime = MaxHeatTime.

HeatTimePercent is the percentage of CycleTime the HeatOut is set.

$$HeatTimePercent = \frac{HeatTime}{CycleTime} \times 100$$

CoolTime is the amount of time within CycleTime that the cool output is to be turned on.

$$CoolTime = \frac{In - MinCoolIn}{MaxCoolIn - MinCoolIn} \times CycleTime$$

- If CoolTime < MinCoolTime, set CoolTime = 0.
- If CoolTime > MaxCoolTime, limit CoolTime = MaxCoolTime.

CoolTimePercent is the percentage of CycleTime CoolOut is set.

$$CoolTimePercent = \frac{CoolTime}{CycleTime} \times 100$$

The instruction controls heat and cool outputs using these rules:

- Set HeatOut if HeatTime ≥ the internal cycle time accumulator. Clear HeatOut when the internal cycle timer > HeatTime.

- Set CoolOut if CoolTime ≥ the internal cycle time accumulator. Clear CoolOut if the internal cycle timer > CoolTime.

- Clear HeatOut and CoolOut if CycleTime = 0.

Arithmetic Status Flags: Arithmetic status flags are set for the HeatTimePercent and CoolTimePercent outputs.

Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	HeatOut and CoolOut are cleared.	HeatOut and CoolOut are cleared.
instruction first scan	The internal cycle timer is reset.	The internal cycle timer is reset.
instruction first run	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. he instruction executes.
postscan	No action taken.	No action taken.

Example: In this example, the PIDE instruction executes in a slow, lower priority task because it is a slow, temperature loop. The output of the PIDE instruction is a controller-scoped tag because it becomes the input to an SRTP instruction. The SRTP instruction executes in a faster, higher priority task so that the pulse outputs are more accurate.

Structured Text

place the PIDE instruction in a slow, lower priority task

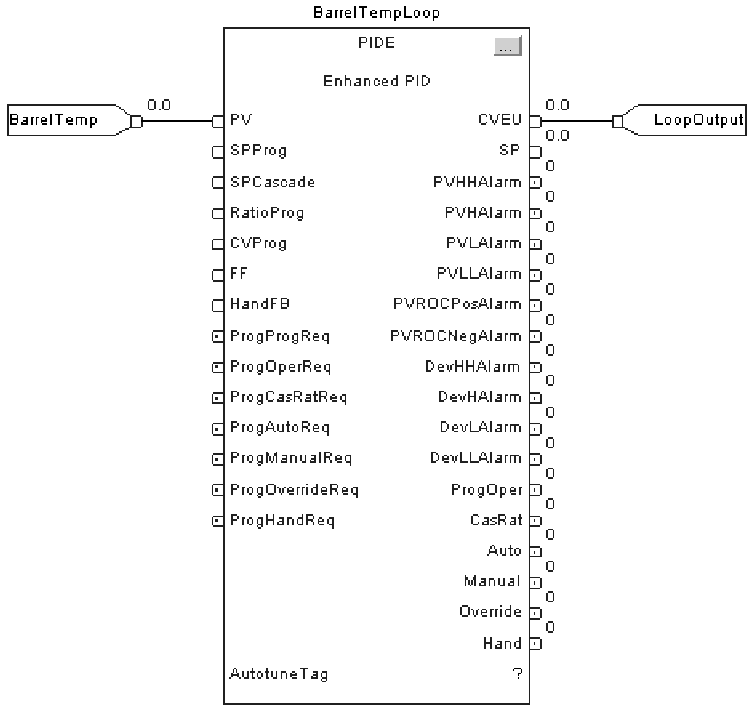
```
BarrelTempLoop.PV := BarrelTemp;
PIDE(BarrelTempLoop);
LoopOutput := BarrelTempLoop.CVEU;
```

place the SRTP instruction in a faster, higher-priority task

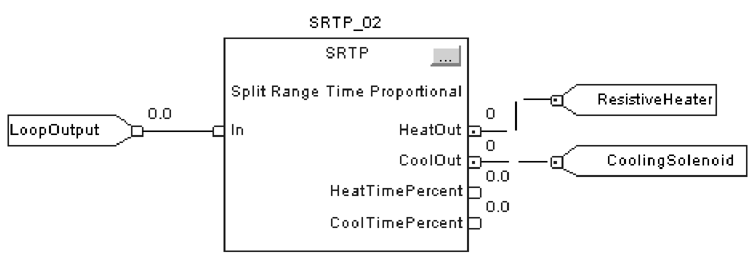
```
SRTP_02.In := LoopOutput;
SRTP(SRTP_02);
ResistiveHeater := SRTP_02.HeatOut;
CoolingSolenoid := SRTP_02.CoolOut;
```

Function Block

place the PIDE instruction in a slow, lower priority task



place the SRTP instruction in a faster, higher-priority task



Totalizer (TOT)

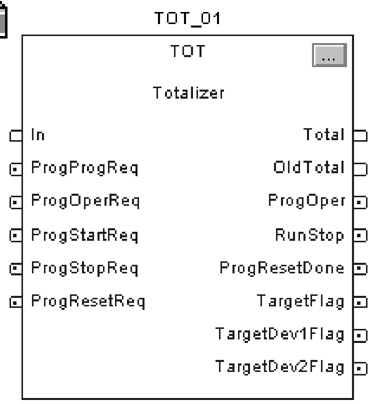
The TOT instruction provides a time-scaled accumulation of an analog input value.

Operands:

```
TOT(TOT_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
TOT tag	TOTALIZER	structure	TOT structure



Function Block

Operand:	Type:	Format:	Description:
TOT tag	TOTALIZER	structure	TOT structure

TOTALIZER Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
InFault	BOOL	Bad health indicator of In. If set, it indicates that the input signal has an error, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Total is not updated. Default is cleared.

Input Parameter:	Data Type:	Description:
TimeBase	DINT	The timebase input. The time base of the totalization based on the In engineering units. **Value:** **Description:** 0 seconds 1 minutes 2 hours 3 days For example, use TimeBase = minutes if In has units of gal/min. If this value is invalid, the instruction sets the appropriate bit in Status and does not update the Total. For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 3 Default = 0
Gain	REAL	The multiplier of the incremental totalized value. The user can use the Gain to convert the units of totalization. For example, use the Gain to convert gal/min to a total in barrels. Valid = any float Default = 1.0
ResetValue	REAL	The reset value input. The reset value of Total when OperResetReq or ProgResetReq transitions from cleared to set. Valid = any float Default = 0.0
Target	REAL	The target value for the totalized In. Valid = any float Default = 0.0
TargetDev1	REAL	The large deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
TargetDev2	REAL	The small deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
LowInCutoff	REAL	The instruction low input cutoff input. When the In is at or below the LowInCutoff value, totalization ceases. Valid = any float Default = 0.0
ProgProgReq	BOOL	Program program request. Set to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction in Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set to request Operator control. Holding this set locks the instruction in Operator control. Default is cleared.
ProgStartReq	BOOL	The program start request input. Set to request totalization to start. Default is cleared.
ProgStopReq	BOOL	The program stop request input. Set to request totalization to stop. Default is cleared.
ProgResetReq	BOOL	The program reset request input. Set to request the Total to reset to the ResetValue. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input. Default is cleared.

Input Parameter:	Data Type:	Description:
TimeBase	DINT	The timebase input. The time base of the totalization based on the In engineering units. **Value:** **Description:** 0 seconds 1 minutes 2 hours 3 days For example, use TimeBase = minutes if In has units of gal/min. If this value is invalid, the instruction sets the appropriate bit in Status and does not update the Total. For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 3 Default = 0
Gain	REAL	The multiplier of the incremental totalized value. The user can use the Gain to convert the units of totalization. For example, use the Gain to convert gal/min to a total in barrels. Valid = any float Default = 1.0
ResetValue	REAL	The reset value input. The reset value of Total when OperResetReq or ProgResetReq transitions from cleared to set. Valid = any float Default = 0.0
Target	REAL	The target value for the totalized In. Valid = any float Default = 0.0
TargetDev1	REAL	The large deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
TargetDev2	REAL	The small deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
LowInCutoff	REAL	The instruction low input cutoff input. When the In is at or below the LowInCutoff value, totalization ceases. Valid = any float Default = 0.0
ProgProgReq	BOOL	Program program request. Set to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction in Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set to request Operator control. Holding this set locks the instruction in Operator control. Default is cleared.
ProgStartReq	BOOL	The program start request input. Set to request totalization to start. Default is cleared.
ProgStopReq	BOOL	The program stop request input. Set to request totalization to stop. Default is cleared.
ProgResetReq	BOOL	The program reset request input. Set to request the Total to reset to the ResetValue. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input. Default is cleared.

Input Parameter:	Data Type:	Description:
TimeBase	DINT	The timebase input. The time base of the totalization based on the In engineering units. **Value:** **Description:** 0 seconds 1 minutes 2 hours 3 days For example, use TimeBase = minutes if In has units of gal/min. If this value is invalid, the instruction sets the appropriate bit in Status and does not update the Total. For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 3 Default = 0
Gain	REAL	The multiplier of the incremental totalized value. The user can use the Gain to convert the units of totalization. For example, use the Gain to convert gal/min to a total in barrels. Valid = any float Default = 1.0
ResetValue	REAL	The reset value input. The reset value of Total when OperResetReq or ProgResetReq transitions from cleared to set. Valid = any float Default = 0.0
Target	REAL	The target value for the totalized In. Valid = any float Default = 0.0
TargetDev1	REAL	The large deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
TargetDev2	REAL	The small deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
LowInCutoff	REAL	The instruction low input cutoff input. When the In is at or below the LowInCutoff value, totalization ceases. Valid = any float Default = 0.0
ProgProgReq	BOOL	Program program request. Set to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction in Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set to request Operator control. Holding this set locks the instruction in Operator control. Default is cleared.
ProgStartReq	BOOL	The program start request input. Set to request totalization to start. Default is cleared.
ProgStopReq	BOOL	The program stop request input. Set to request totalization to stop. Default is cleared.
ProgResetReq	BOOL	The program reset request input. Set to request the Total to reset to the ResetValue. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input. Default is cleared.

Input Parameter:	Data Type:	Description:
TimeBase	DINT	The timebase input. The time base of the totalization based on the In engineering units. **Value:** **Description:** 0 seconds 1 minutes 2 hours 3 days For example, use TimeBase = minutes if In has units of gal/min. If this value is invalid, the instruction sets the appropriate bit in Status and does not update the Total. For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 3 Default = 0
Gain	REAL	The multiplier of the incremental totalized value. The user can use the Gain to convert the units of totalization. For example, use the Gain to convert gal/min to a total in barrels. Valid = any float Default = 1.0
ResetValue	REAL	The reset value input. The reset value of Total when OperResetReq or ProgResetReq transitions from cleared to set. Valid = any float Default = 0.0
Target	REAL	The target value for the totalized In. Valid = any float Default = 0.0
TargetDev1	REAL	The large deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
TargetDev2	REAL	The small deviation pre-target value of the Total compared to the Target. This value is expressed as a deviation from the Target. Valid = any float Default = 0.0
LowInCutoff	REAL	The instruction low input cutoff input. When the In is at or below the LowInCutoff value, totalization ceases. Valid = any float Default = 0.0
ProgProgReq	BOOL	Program program request. Set to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction in Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set to request Operator control. Holding this set locks the instruction in Operator control. Default is cleared.
ProgStartReq	BOOL	The program start request input. Set to request totalization to start. Default is cleared.
ProgStopReq	BOOL	The program stop request input. Set to request totalization to stop. Default is cleared.
ProgResetReq	BOOL	The program reset request input. Set to request the Total to reset to the ResetValue. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input. Default is cleared.

Input Parameter:	Data Type:	Description:
OperOperReq	BOOL	Operator operator request. Set by the operator interface to request Operator control. The instruction clears this input. Default is cleared.
OperStartReq	BOOL	The operator start request input. Set by the operator interface to request totalization to start. The instruction clears this input. Default is cleared.
OperStopReq	BOOL	The operator stop request input. Set by the operator interface to request totalization to stop. The instruction clears this input. Default is cleared.
OperResetReq	BOOL	The operator reset request input. Set by the operator interface to request totalization to reset. The instruction clears this input. Default is cleared.
ProgValueReset	BOOL	Reset program control values. When set, clear all the program request inputs each execution of the instruction. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Total	REAL	The totalized value if In. Arithmetic status flags are set for this output.
OldTotal	REAL	The value of the total before a reset occurred. You can monitor this value to read the exact total just before the last reset.
ProgOper	BOOL	Program/operator control indicator. Set when in Program control. Cleared when in Operator control.
RunStop	BOOL	The indicator of the operational state of the totalizer. Set when the TOT instruction is running. Cleared when the TOT instruction is stopped.
ProgResetDone	BOOL	The indicator that the TOT instruction has completed a program reset request. Set when the instruction resets as a result of ProgResetReq. You can monitor this to determine that a reset successfully completed. Cleared when ProgResetReq is cleared.
TargetFlag	BOOL	The flag for Total. Set when Total ≥ Target.

Output Parameter:	Data Type:	Description:
TargetDev1Flag	BOOL	The flag for TargetDev1. Set when Total ≥ Target - TargetDev1.
TargetDev2Flag	BOOL	The flag for TargetDev2. Set when Total ≥ Target - TargetDev2.
LowInCutoffFlag	BOOL	The instruction low input cutoff flag output. Set when In ≤ LowInCutoff.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
InFaulted (Status.1)	BOOL	In value faulted.
TimeBaseInv (Status.2)	BOOL	Invalid TimeBase value.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value. This can occur if OversampleDT is invalid in oversample timing mode.

Description:

This instruction typically totals the amount of a material added over time, based on a flow signal.

The TOT instruction supports:

- Time base selectable as seconds, minutes, hours, or days.
- You can specify a target value and up to two pre-target values. Pre-target values are typically used to switch to a slower feed rate. Digital flags announce the reaching of the target or pre-target values.
- A low flow input cutoff that you can use to eliminate negative totalization due to slight flowmeter calibration inaccuracies when the flow is shut off.
- Operator or program capability to start/stop/reset.
- A user defined reset value.
- Trapezoidal-rule numerical integration to improve accuracy.
- The internal totalization is done with double precision math to improve accuracy.

Monitoring the TOT instruction

There is an operator faceplate available for the TOT instruction. For more information, see appendix Function Block Faceplate Controls.

Arithmetic Status Flags: Arithmetic status flags are set for the Total output.

Fault Conditions: none

Execution:

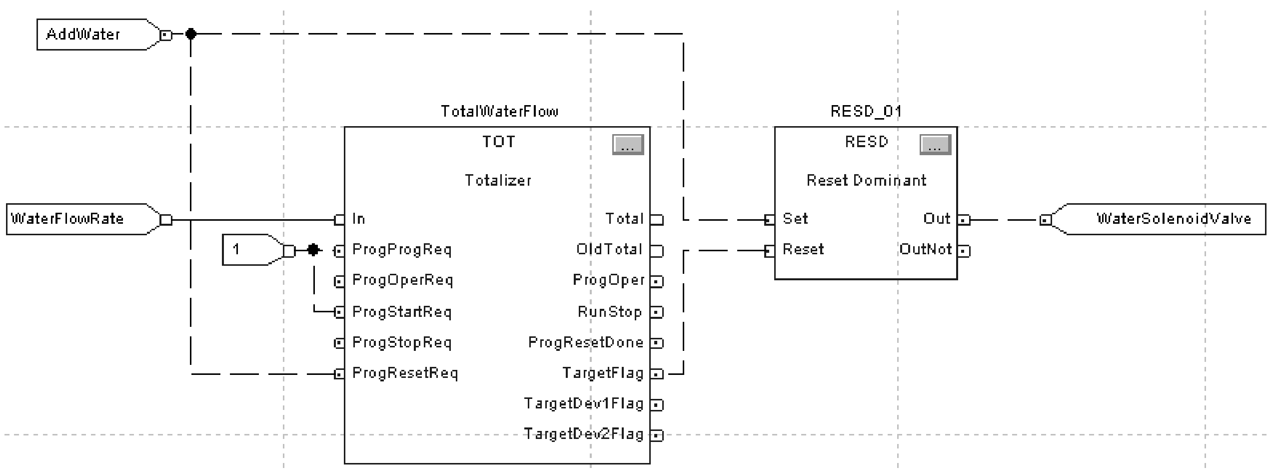
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	All operator request inputs are cleared. If ProgValueReset is set, then all program request inputs are cleared.	
instruction first run	The instruction initializes the internal parameters. Total = ResetValue. OldTotal = 0.0. ProgOper is cleared.	
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. he instruction executes.
postscan	No action taken.	No action taken.

Example: In this example, the TOT instruction meters a target quantity of water into a tank and shuts off the flow once the proper amount of water has been added. When the AddWater pushbutton is pressed, the TOT instruction resets and starts totalizing the amount of water flowing into the tank. Once the Target value is reached, the TOT instruction sets the TargetFlag output, which causes the solenoid valve to close. For this example, the TOT instruction was “locked” into Program Run by setting the ProgProgReq and ProgStartReq inputs. This is done for this example because the operator never needs to directly control the TOT instruction.

Structured Text

```
TotalWaterFlow.In := WaterFlowRate;
TotalWaterFlow.ProgProgReq := 1;
TotalWaterFlow.ProgStartReq := 1;
TotalWaterFlow.ProgResetReq := AddWater;
TOT(TotalWaterFlow);

RESD_01.Set := AddWater;
RESD_01.Reset := TotalWaterFlow.TargetFlag;
RESD(RESD_01);

WaterSolenoidValve := RESD_01.Out;
```

Function Block



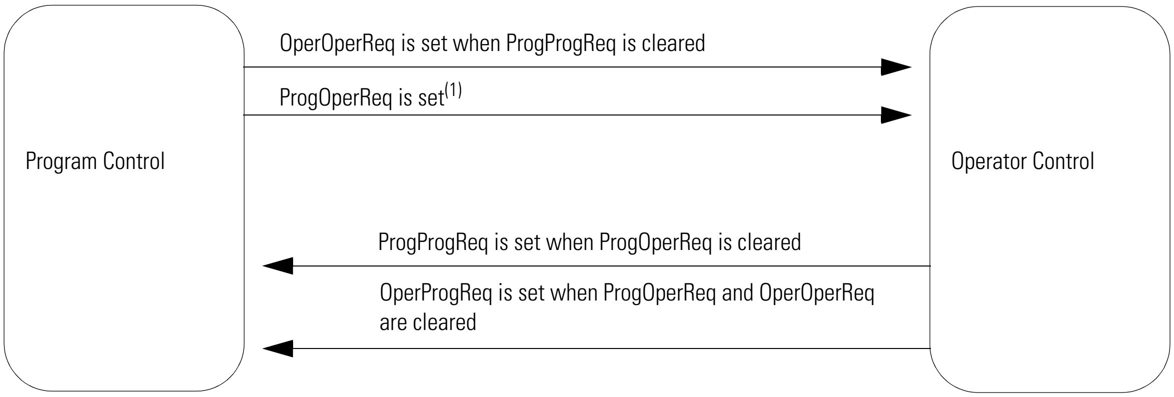
Check for low input cutoff

If (In ≤ LowInCutoff), the instruction sets LowInCutoffFlag and makes In_{n-1} = 0.0. Otherwise, the instruction clears LowInCutoffFlag.

When the LowInCutoffFlag is set, the operation mode is determined, but totalization ceases. When LowInCutoffFlag is cleared, totalization continues that scan.

Operating modes

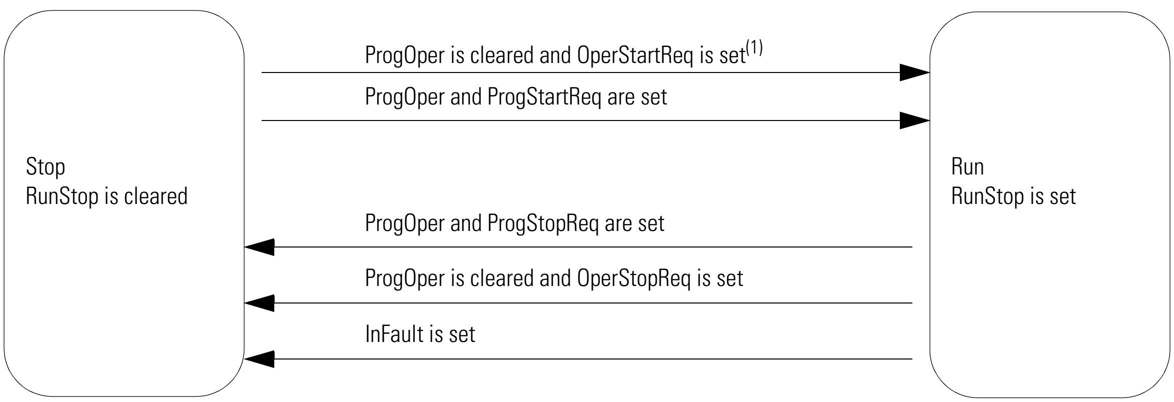
The following diagram shows how the TOT instruction changes between Program control and Operator control.



(1) The instruction remains in operator control mode when ProgOperReq is set.

For more information on program and operator control, see page B-13.

The following diagram shows how the TOT instruction changes between Run and Stop modes.



(1) The stop requests take precedence over start requests.

(2) The first scan in run after a stop, the totalization is not evaluated, but In_{n-1} is updated. During the next scan, totalization resumes.

All operator request inputs are cleared at the end of each scan. If ProgValueReset is set, all program request inputs are cleared at the end of each scan.

Resetting the TOT instruction

When ProgResetReq transitions to set while ProgOper is set, the following happens:

- OldTotal = Total
- Total = ResetValue
- ProgResetDone is set

If ProgResetReq is cleared and ProgResetDone is set then ProgResetDone is cleared

When OperResetReq transitions to set while ProgOper is cleared, the following happens:

- OldTotal = Total
- Total = ResetValue

Calculating the totalization

When RunStop is set and LowInCutoffFlag is cleared, the following equation performs the totalization calculation.

$$Total_n = Total_{n-1} + Gain \times \frac{DeltaT}{2 \times TimeBase} \times (In_n + In_{n-1})$$

where TimeBase is:

Value:	Condition:
1	TimeBase = 0 (seconds)
60	TimeBase = 1 (minutes)
3600	TimeBase = 2 (hours)
86400	TimeBase = 3 (days)

Determining if target values have been reached

Once the totalization has been calculated, these rules determine whether the target or pre-target values have been reached:

- TargetFlag is set when Total ≥ Target
- TargetDev1Flag is set when Total ≥ (Target - TargetDev1)
- TargetDev2Flag is set when Total ≥ (Target - TargetDev2)

Drives Instructions
(INTG, PI, PMUL, SCRV, SOC, UPDN)

Introduction

These drives instructions are available:

If you want to:	Use this instruction:	Available in these languages:	See page:
execute a integral operation.	Integrator (INTG)	structured text function block	2-2
execute a PI algorithm.	Proportional + Integral (PI)	structured text function block	2-8
provide an interface from a position input module, such as a resolver or encoder feedback module, to the digital system by computing the change in input from one scan to the next.	Pulse Multiplier (PMUL)	structured text function block	2-20
perform a ramp function with an added jerk rate.	S-Curve (SCRV)	structured text function block	2-28
use a gain term, a first order lag, and a second order lead.	Second-Order Controller (SOC)	structured text function block	2-38
add and subtract two inputs into an accumulated value.	Up/Down Accumulator (UPDN)	structured text function block	2-47

Integrator (INTG)

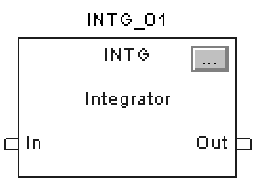
The INTG instruction implements an integral operation. This instruction is designed to execute in a task where the scan rate remains constant.

Operands:

```
INTG(INTG_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
INTG tag	INTEGRATOR	structure	INTG structure



Function Block

Operand:	Type:	Format:	Description:
INTG tag	INTEGRATOR	structure	INTG structure

INTEGRATOR Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	Request to initialize control algorithm. Output = InitialValue as long as Initialize is set. Valid = any float Default = 0.0
InitialValue	REAL	The initial value for instruction. Output = InitialValue as long as Initialize is set. Valid = any float Default = 0.0
IGain	REAL	The integral gain multiplier. If IGain < 0; the instruction sets IGain = 0.0, sets the appropriate bit in Status, and leaves the Output unchanged. Valid = 0.0 to maximum positive float Default = 0.0
HighLimit	REAL	The high limit value for Out. If HighLimit ≤ LowLimit, the instruction sets HighAlarm and LowAlarm, sets the appropriate bit in Status, and sets Out = LowLimit. Valid = any float Default = maximum positive float
LowLimit	REAL	The low limit value for Out. If HighLimit ≤ LowLimit, the instruction sets HighAlarm and LowAlarm, sets the appropriate bit in Status, and sets Out = LowLimit. Valid = any float Default = maximum negative float

Input Parameter:	Data Type:	Description:
HoldHigh	BOOL	Hold output high request. When set, Out is not allowed to increase in value. Default is cleared.
HoldLow	BOOL	Hold output low request. When set, Out is not allowed to decrease in value. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
HighAlarm	BOOL	High limit alarm indicator. When Out ≥ HighLimit, HighAlarm is set and the output is limited to the value of HighLimit.
LowAlarm	BOOL	Low limit alarm indicator. When Out ≤ LowLimit, LowAlarm is set and the output is limited to the value of LowLimit.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
IGainInv (Status.1)	BOOL	IGain > maximum or IGain < minimum.
HighLowLimsInv (Status.2)	BOOL	HighLimit ≤ LowLimit.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).

Output Parameter:	Data Type:	Description:
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Description: The INTG instruction is designed to execute in a task where the scan rate remains constant.

The INTG instruction executes this control algorithm when Initialize is cleared and DeltaT > 0.

$$Out = IGain \times \frac{In + In_{n-1}}{2} \times DeltaT + Out_{n-1}$$

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. The internal parameters are not updated. In each subsequent scan, the output is computed using the internal parameters from the last scan when the output was valid.

Limiting

The INTG instruction performs windup limiting to stop Out from changing based on the state of the HoldHigh and HoldLow inputs. If HoldHigh is set and Out > Out_{n-1} then Out = Out_{n-1}. If HoldLow is set and Out < Out_{n-1}, then Out = Out_{n-1}.

The INTG instruction also performs output limiting using HighLimit and LowLimit. If Out ≥ HighLimit, then Out = HighLimit and HighAlarm is set. If Out ≤ LowLimit, then Out = LowLimit and LowAlarm is set.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

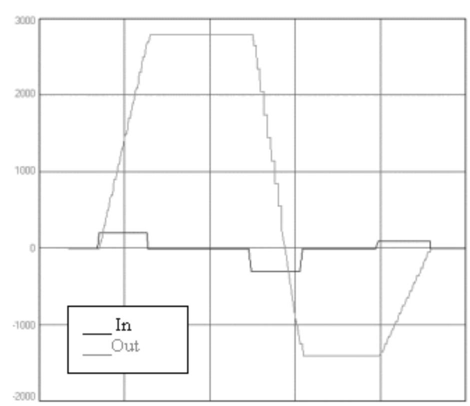
Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	The internal parameters and Out are set to 0. The control algorithm is not executed.	The internal parameters and Out are set to 0. The control algorithm is not executed.
instruction first run	The internal parameters and Out are set 0. The control algorithm is not executed.	The internal parameters and Out are set 0. The control algorithm is not executed.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: In many applications an integral gain component is included in the closed loop regulator design in order to eliminate or minimize error in the system being regulated. A straight proportional-only regulator will not tend to drive error in the system to zero. A regulator that uses proportional and integral gain, however, tends to drive the error signal to zero over a period of time. The INTG instruction uses the following equation to calculate its output.

$$Out = IGain \times \frac{In + In_{n-1}}{2} \times DeltaT + Out_{n-1}$$

In this chart, the input to the block moves from 0 to +200 units. During this period, the output of the block integrates to 2800 units. As In changes from +200 units to 0 units, Out maintains at 2800 units. When In transitions from 0 to -300 units, Out slowly integrates down to -1400 units until In transitions back to 0. As In moves from 0 to +100, Out integrates back to 0 where In is set to 0 coincidentally with Out reaching 0.



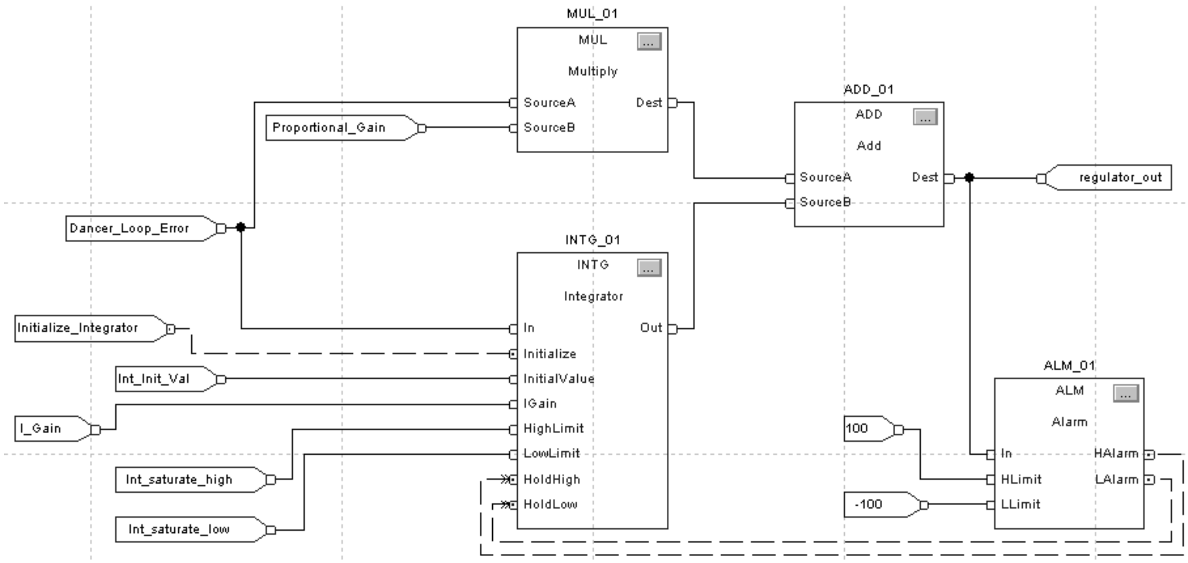
This characteristic of the integrator - continually driving in a specific direction while any input to the function is present or holding at any level during the point where the input is at zero - is what causes a regulator using integral gain to drive toward zero error over a period of time.

The following example shows how the INTG instruction can be used in an application. In many instances, the HighLimit and LowLimit inputs limit the total percentage of control that the integral gain element might have as a function of the regulator's total output. The HoldHigh and HoldLow inputs, on the other hand, can be used to prevent the output from moving further in either the positive or negative direction. In this example, if the regulator output is already saturated at 100%, the HoldHigh and HoldLow inputs prevent the INTG instruction from "winding-up" in a direction which is already beyond the limits of the controlled variable.

Structured Text

```
INTG_01.IN := Dancer_Loop_Error;
INTG_01.Initialize := Initialize_Integrator;
INTG_01.InitialValue := Int_Init_Val;
INTG_01.IGain := I_Gain;
INTG_01.HighLimit := Int_saturate_high;
INTG_01.LowLimit := Int_saturate_low;
INTG_01.HoldHigh := ALM_01.HAlarm;
INTG_01.HoldLow := ALM_01.LAlarm;
INTG(INTG_01);

regulator_out := (Dancer_Loop_Error*Proportional_Gain)
    + INTG_01.Out;

ALM_01.In := regulator_out;
ALM_01.HLimit := 100;
ALM_01.LLimit := -100;
ALM(ALM_01);
```

Function Block



Proportional + Integral (PI)

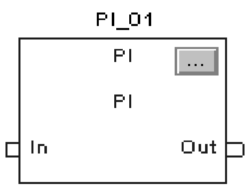
The PI instruction provides two methods of operation. The first method follows the conventional PI algorithm in that the proportional and integral gains remain constant over the range of the input signal (error). The second method uses a non-linear algorithm where the proportional and integral gains vary over the range of the input signal. The input signal is the deviation between the setpoint and feedback of the process.

Operands:

```
PI(PI_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
PI tag	PROP_INT	structure	PI structure



Function Block

Operand:	Type:	Format:	Description:
PI tag	PROP_INT	structure	PI structure

PROP_INT Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The process error signal input. This is the difference between setpoint and feedback. Valid = any float Default = 0.0
Initialize	BOOL	The instruction initialization command. When set, Out and internal integrator are set equal to the value of InitialValue. Default is cleared.
InitialValue	REAL	The initial value input. When Initialize is set, Out and integrator are set to the value of InitialValue. The value of InitialValue is limited using HighLimit and LowLimit. Valid = any float Default = 0
Kp	REAL	The proportional gain. This affects the calculated value for both the proportional and integral control algorithms. If invalid, the instruction clamps Kp at the limits and sets the appropriate bit in Status. Valid = any float > 0.0 Default = minimum positive float

Input Parameter:	Data Type:	Description:
Wld	REAL	The lead frequency in radians/second. This affects the calculated value of the integral control algorithm. If invalid, the instruction clamps Wld at the limits and sets the appropriate bit in Status. Valid = see the Description section below for valid ranges Default = 0.0
HighLimit	REAL	The high limit value. This is the maximum value for Out. If HighLimit ≤ LowLimit, the instruction sets HighAlarm and LowAlarm, sets the appropriate bit in Status, and sets Out = LowLimit. Valid = LowLimit < HighLimit ≤ maximum positive float Default = maximum positive float
LowLimit	REAL	The low limit value. This is the minimum value for Out. If HighLimit ≤ LowLimit, the instruction sets HighAlarm and LowAlarm, sets the appropriate bit in Status, and sets Out = LowLimit. Valid = maximum negative float ≤ LowLimit < HighLimit Default = maximum negative float
HoldHigh	BOOL	The hold high command. When set, the value of the internal integrator is not allowed to increase in value. Default is cleared.
HoldLow	BOOL	The hold low command. When set, the value of the internal integrator is not allowed to decrease in value. Default is cleared.
ShapeKpPlus	REAL	The positive Kp shaping gain multiplier. Used when In is ≥ 0. If invalid, the instruction clamps ShapeKpPlus at the limits and sets the appropriate bit in Status. Not used when NonLinearMode is cleared. Valid = 0.1 to 10.0 Default = 1.0
ShapeKpMinus	REAL	The negative Kp shaping gain multiplier. Used when In is < 0. If invalid, the instruction clamps ShapeKpMinus at the limits and sets the appropriate bit in Status. Not used when NonLinearMode is cleared. Valid = 0.1 to 10.0 Default = 1.0
KpInRange	REAL	The proportional gain shaping range. Defines the range of In (error) over which the proportional gain increases or decreases as a function of the ratio of | In | / KpInRange. When | In | > KpInRange, the instruction calculates the change in proportional error using entered the Kp shaping gain x (In - KpInRange). If invalid, the instruction clamps KpInRange at the limits and sets the appropriate bit in Status. Not used when NonLinearMode is cleared. Valid = any float > 0.0 Default = maximum positive float
ShapeWldPlus	REAL	The positive Wld shaping gain multiplier. Used when In is ≥ 0. If invalid, the instruction clamps ShapeWldPlus at the limits and sets the appropriate bit in Status. Not used when NonLinearMode is cleared. Valid = 0.0 to 10.0 Default = 1.0
ShapeWldMinus	REAL	The negative Wld shaping gain multiplier. Used when In is < 0. If invalid, the instruction clamps ShapeWldMinus at the limits and sets the appropriate bit in Status. Not used when NonLinearMode is cleared. Valid = 0.0 to 10.0 Default = 1.0

Input Parameter:	Data Type:	Description:
WIdInRange	REAL	The integral gain shaping range. Defines the range of In (error) over which integral gain increases or decreases as a function of the ratio of | In | / WIdInRange. When |In| > WIdInRange, the instruction limits In to WIdInRange when calculating integral error. If invalid, the instruction clamps WIdInRange at the limits and sets the appropriate bit in Status. Not used when NonLinearMode is cleared. Valid = any float > 0.0 Default = maximum positive float
NonLinearMode	BOOL	Enable the non-linear gain mode. When set, the instruction uses the non-linear gain mode selected by ParabolicLinear to compute the actual proportional and integral gains. When cleared, the instruction disables the non-linear gain mode and uses the Kp and WId values as the proportional and integral gains. Default is cleared.
ParabolicLinear	BOOL	Selects the non-linear gain mode. The modes are linear or parabolic. When set, the instruction uses the parabolic gain method of $y = a * x^2 + b$ to calculate the actual proportional and integral gains. If cleared, the instruction uses the linear gain method of $y = a * x + b$. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the PI algorithm. Arithmetic status flags are set for this output.
HighAlarm	BOOL	The maximum limit alarm indicator. Set when the calculated value for Out ≥ HighLimit and the output and integrator are clamped at HighLimit.
LowAlarm	BOOL	The minimum limit alarm indicator. Set when the calculated value for Out ≤ LowLimit and output and integrator are clamped at LowLimit.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.

Output Parameter:	Data Type:	Description:
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
KpInv (Status.1)	BOOL	Kp < minimum or Kp > maximum.
WldInv (Status.2)	BOOL	Wld < minimum or Wld > maximum.
HighLowLimsInv (Status.3)	BOOL	HighLimit ≤ LowLimit.
ShapeKpPlusInv (Status.4)	BOOL	ShapeKpPlus < minimum or ShapeKpPlus > maximum.
ShapeKpMinusInv (Status.5)	BOOL	ShapeKpMinus < minimum or ShapeKpMinus > maximum.
KpInRangeInv (Status.6)	BOOL	KpInRange < minimum or KpInRange > maximum.
ShapeWldPlusInv (Status.7)	BOOL	ShapeWldPlus < minimum or ShapeWldPlus > maximum.
ShapeWldMinusInv (Status.8)	BOOL	ShapeWldMinus < minimum or ShapeWldMinus > maximum.
WldInRangeInv (Status.9)	BOOL	WldInRange < minimum or WldInRange > maximum.
TimingModeInv (Status.27)	BOOL	Invalid timing mode. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaT (Status.31)	BOOL	Invalid DeltaT value.

Description:

The PI instruction uses the position form of the PI algorithm. This means the gain terms are applied directly to the input signal, rather than to the change in the input signal. The PI instruction is designed to execute in a task where the scan rate remains constant.

In the non-linear algorithm, the proportional and integral gains vary as the magnitude of the input signal changes. The PI instruction supports two non-linear gain modes: linear and parabolic. In the linear algorithm, the gains vary linearly as the magnitude of input changes. In the parabolic algorithm, the gains vary according to a parabolic curve as the magnitude of input changes.

The PI instruction calculates Out using this equation:

$$Kp \times \frac{s + Wld}{s}$$

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. The internal parameters are not updated. In each subsequent scan, the output is computed using the internal parameters from the last scan when the output was valid.

Operating in linear mode

In linear mode, the non-linear gain mode is disabled. The Kp and Wld values are the proportional and integral gains used by the instruction. The instruction calculates the value for Out using these equations:

Value:	Equation:
ITerm	$Kp \times Wld \times \frac{WldInput + WldInput_{n-1}}{2} \times DeltaT + ITerm_{n-1}$ where DeltaT is in seconds
PTerm	$Kp \times In$
Out	$ITerm + PTerm$

with these limits on Wld:

LowLimit > 0.0

HighLimit = $\frac{0.7\pi}{DeltaT}$

WldInput = In

Operating in non-linear mode

In non-linear mode, the instruction uses the non-linear gain mode selected by ParabolicLinear to compute the actual proportional and integral gains.

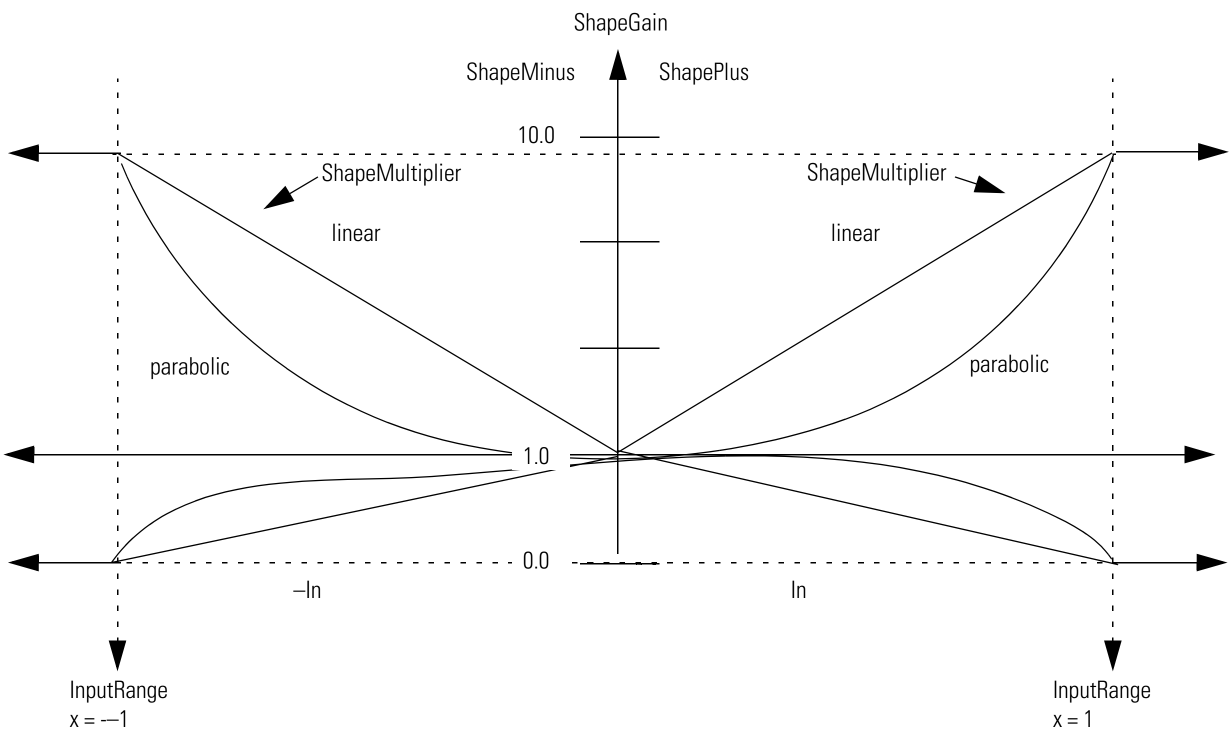
The gains specified by Kp and Wld are multiplied by 1.0 when In = 0. Separate proportional and integral algorithms increase or decrease the proportional or integral gain as the magnitude of error changes. These algorithms use the input range and shaping gain parameters to compute the actual proportional and integral gains. Input range defines the range of In (i.e. error) over which the gain is shaped. Input ranges are set by the two KpInRange and WldInRange. Shaping gain defines the gain multiplier for the quadrant controlled by the shaping gain parameter. Shaping gains are set by ShapeKpPlus, ShapeKpMinus, ShapeWldPlus and ShapeWldMinus.

The ParabolicLinear input selects the non-linear gain mode. If ParabolicLinear is cleared, linear mode is selected. If ParabolicLinear is set, parabolic mode is selected.

To configure a particular shaping gain curve, enter a shaping gain 0.0–10.0 for integral shaping, a shaping gain 0.1–10.0 for proportional shaping, and the input range over which shaping is to be applied. Kp and Wld are multiplied by the calculated ShapeMultiplier to obtain the actual proportional and integral gains. Entering a shaping gain of 1.0 disables the non-linear algorithm that calculates the proportional or integral gain for the quadrant.

When the magnitude of In (error) is greater then InRange then the ShapeMultiplier equals the value computed when | In | was equal to InRange.

The following diagram illustrates the maximum and minimum gain curves that represent the parabolic and linear gain equations.



The instruction calculates the value for Out using these equations:

Value:	Equations:
Kp shaping gain multiplier	If In ≥ 0 then: $KpShapeGain = ShapeKpPlus$ $KpRange = KpInRange$ Else: $KpShapeGain = ShapeKpMinus$ $KpRange = -KpInRange$
Kp input ratio	If |In| ≤ KpInRange: $KpInputRatio = \|In\| \times \frac{1}{KpInRange}$ Else: $KpInputRatio = 1$
Kp ratio	If not parabolic mode: $KpRatio = KpInputRatio \times 0.5$ If parabolic mode: $KpRatio = KpInputRatio^2 \times 0.333$
Kps shaping gain	$Kps = Kp \times (((KpShapeGain - 1) \times KpRatio) + 1)$
Proportional output	If |In| ≤ KpInRange: $PTerm = Kps \times In$ Else, limit gain: $PTerm = Kps \times KpRange + (In - KpRange) \times KpShape$
Wld shaping gain	If In ≥ 0 then: $WldShapeGain = ShapeWldPlus$ Else: $WldShapeGain = ShapeWldMinus$
Wld input	If In > WldRange then: $WldInput = WldInRange$ Else if In < –WldInRange then: $WldInput = -WldInRange$ Else: $WldInput = In$
Wld input ratio	If |In| ≤ WldInRange: $WldInputRange = \|In\| \times \frac{1}{WldInRange}$ Else: $WldInputRange = 1$

Value:	Equations:
Wld ratio	If not parabolic mode: $WldRatio = WldInputRatio$ If parabolic mode: $WldRatio = WldInputRatio^2$
Wlds shaping gain	$Wlds = Wld \times (((WldShapeGain - 1) \times WldRatio) + 1)$
Wlds limits	$LowLimit > 0$ $HighLimit = \frac{0.7\pi}{DeltaT}$
Integral output	$ITerm = Kps \times Wlds \times \frac{(WldInput + WldInput_{n-1})}{2} \times DeltaT + ITerm_{n-1}$
Output	$Out = PTerm + ITerm$

Limiting

The instruction stops the ITerm windup based on the state of the hold inputs.

Condition:	Action:
If HoldHigh is set **and** $ITerm > ITerm_{n-1}$	$ITerm = ITerm_{n-1}$
If HoldLow is set **and** $ITerm < ITerm_{n-1}$	$ITerm = ITerm_{n-1}$

The instruction also stops integrator windup based on the HighLimit and LowLimit values.

Condition:	Action:
Integrator > HighLimit	Integrator = HighLimit
Integrator < LowLimit	Integrator = LowLimit

The instructions limits the value of Out based on the HighLimit and LowLimit values.

Condition:	Action:
HighLimit ≤ LowLimit	Out = LowLimit ITerm = LowLimit HighLowLimsInv is set HighAlarm is set LowAlarm is set WldInput = 0
Out ≥ HighLimit	Out = HighLimit ITerm = ITerm_{n-1} HighAlarm is set
ITerm > HighLimit	ITerm = HighLimit
Out ≤ LowLimit	Out = LowLimit ITerm = ITerm_{n-1} LowAlarm is set
ITerm < LowLimit	ITerm = LowLimit

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

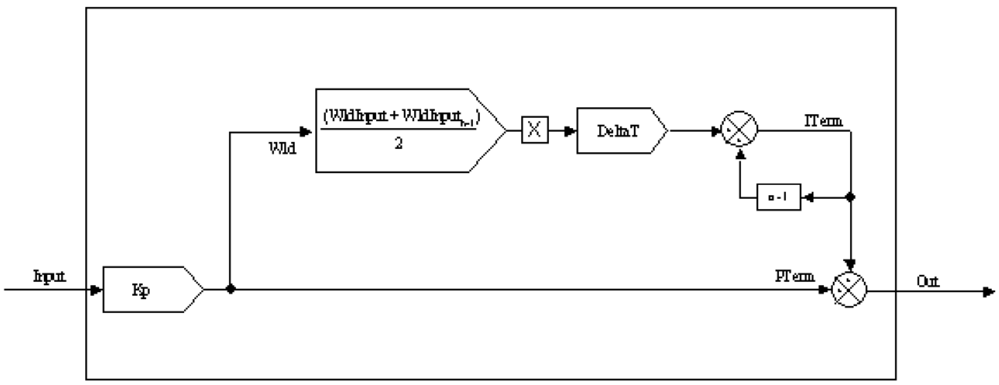
Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	Out = 0 The control algorithm is not executed.	Out = 0 The control algorithm is not executed.
instruction first run	Out = 0 The control algorithm is not executed.	Out = 0 The control algorithm is not executed.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The PI instruction is a regulating instruction with proportional and integral gain components. The integral gain component is set by the user in radians/sec; this sets the basic frequency response of the PI regulator. The proportional gain sets the overall gain of the block, including the proportional AND integral gain of the block.

Excluding initialization and holding/clamping functionality, the following diagram shows the PI block's basic regulating loop while in the linear mode.

PI Instruction: Linear Mode

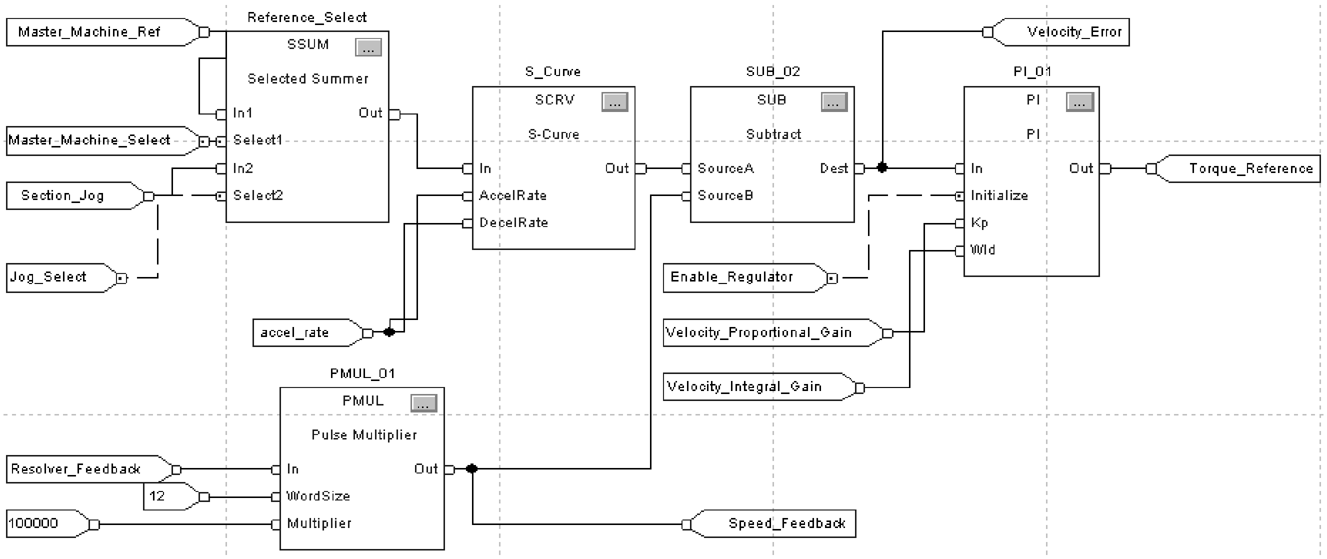


The following example shows the PI instruction used as a velocity regulator. In this example, velocity error is created by subtracting the velocity feedback signal (see the PMUL instruction example) from the system's velocity reference (through the SCRV instruction). Velocity error is driven directly into the PI instruction, which acts on this signal according to the function shown in the diagram above.

Structured Text

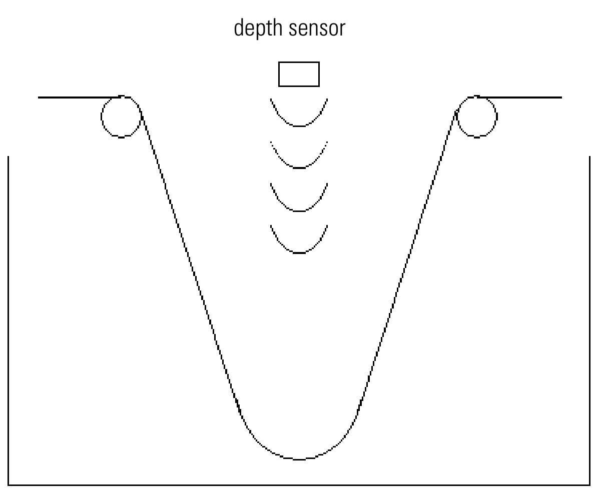
```
Reference_Select.In1 := Master_Machine_Ref;
Reference_Select.Select1 := Master_Machine_Select;
Reference_Select.In2 := Section_Jog;
Reference_Select.Select2 := Jog_Select;
SSUM(Reference_Select);

S_Curve.In := Reference_Select.Out;
S_Curve.AccelRate := accel_rate;
S_Curve.DecelRate := accel_rate;
SCRV(S_Curve);

PMUL_01.In := Resolver_Feedback;
PMUL_01.WordSize := 12;
PMUL_01.Multiplier := 100000;
PMUL(PMUL_01);

Speed_Feedback := PMUL_01.Out;
Velocity_Error := S_Curve.Out - Speed_Feedback;

PI_01.In := Velocity_Error;
PI_01.Initialize := Enable_Regulator;
PI_01.Kp := Velocity_Proportional_Gain;
PI_01.Wld := Velocity_Integral_Gain;
PI(PI_01);

Torque_Reference := PI_01.Out;
```

Function Block



In non-linear mode, the gains of the PI instruction can be shaped as a function of the error being input to the block. This function allows for adaptive gain control and can be used to model a regulator mechanism that more closely matches the process being regulated. One example where this might be used is in a catenary control application where the feedback coming back from a sensor in a looping pit may not reflect a linear signal with respect to the amount of material actually stored. Here, the proportional gains of the PI regulator might be shaped to more closely model the process without using integral components that might constantly "wind-up" and "wind_down."

PI Instruction: Non-Linear Mode



Pulse Multiplier (PMUL)

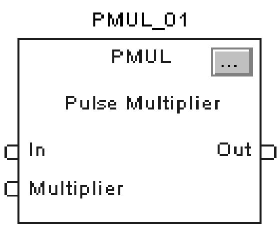
The PMUL instruction provides an interface from a position input module, such as a resolver or encoder feedback module, to the digital system by computing the change in input from one scan to the next. By selecting a specific word size, you configure the PMUL instruction to differentiate through the rollover boundary in a continuous and linear fashion.

Operands:

```
PMUL(PMUL_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
PMUL tag	PULSE_MULTIPLIER	structure	PMUL structure



Function Block

Operand:	Type:	Format:	Description:
PMUL tag	PULSE_MULTIPLIER	structure	PMUL structure

PULSE_MULTIPLIER Structure

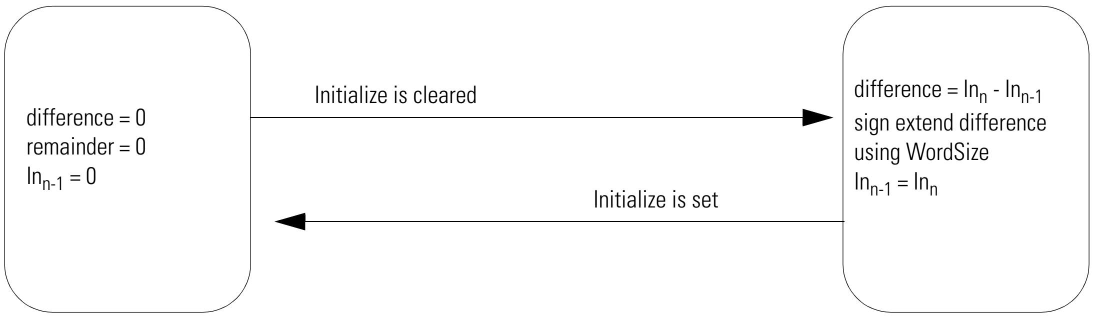
Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	DINT	The analog signal input to the instruction. Valid = any DINT Default = 0
Initialize	BOOL	The initialize input. When set, Out is held at 0.0 and all the internal registers are set to 0. On a set-to-cleared transition, In_{n-1} = InitialValue (not valid for Absolute mode). When cleared, the instruction executes normally. The instruction ignores Initialize if WordSize is invalid. Default is cleared.
InitialValue	DINT	The initial value input. On a set-to-cleared transition of Initialize, In_{n-1} = InitialValue Valid = any DINT Default = 0

Input Parameter:	Data Type:	Description:
Mode	BOOL	The mode input. Set to enable Relative mode. Clear to enable Absolute mode. Default is set.
WordSize	DINT	The word size in bits. Specify the number of bits to use when computing (In_n - In_{n-1}) in Relative mode. WordSize is not used in Absolute mode. When the change in In is greater than 1/2 x $2^{(Wordsize - 1)}$, Out changes sign. When WordSize is invalid, Out is held and the instruction sets the appropriate bit in Status. Valid = 2 to 32 Default = 14
Multiplier	DINT	The multiplier. Divide this value by 100,000 to control the ratio of In to Out. If invalid, the instruction limits the value and sets the appropriate bit in Status. Valid = –1,000,000 to 1,000,000 Default = 100,000

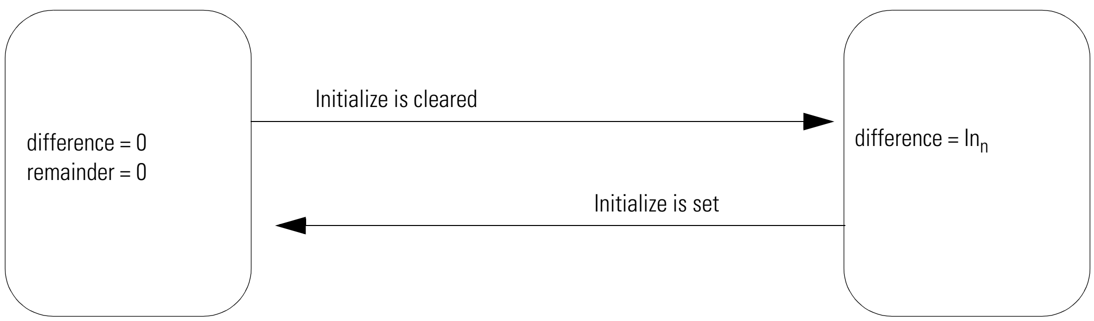
Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The instruction's Out. If the Out calculation overflows, Out is forced to $^{+}/- \infty$ and the appropriate bit in Status is set. Arithmetic status flags are set for this output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
WordSizeInv (Status.1)	BOOL	Invalid WordSize value.
OutOverflow (Status.2)	BOOL	The internal output calculation overflowed.
LostPrecision (Status.3)	BOOL	Out < -2^{24} or Out > 2^{24}. When the instruction converts Out from an integer to a real value, data is lost if the result is greater than $\lvert 2^{24} \rvert$ because the REAL data type is limited to 2^{24}.
MultiplierInv (Status.4)	BOOL	Invalid Multiplier value.

Description: The PMUL instruction operates in Relative or Absolute mode.

In Relative mode, the instruction's output is the differentiation of the input from scan to scan, multiplied by the (Multiplier/100,000). In Relative mode, the instruction saves any remainder after the divide operation in a scan and adds it back in during the next scan. In this manner, position information is not lost over the course of the operation.



In the Absolute mode, the instruction can scale an input, such as position, without losing any information from one scan to the next.



Calculating the output and remainder

The PMUL instruction uses these equations to calculate Out in either relative or absolute mode:

Ans = ((DiffInput x Multiplier) + INT_Remainder)

INT_Out = Ans / 100,000

INT_Remainder= Ans - (INT_Out * 100,000)

Out = INT_Out

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

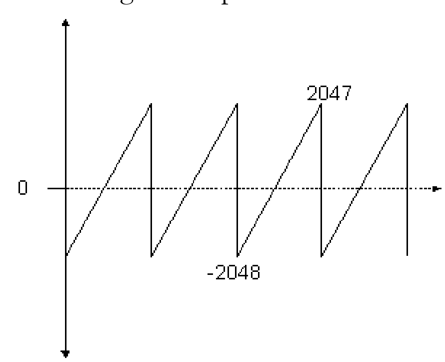
Fault Conditions: none

Execution:

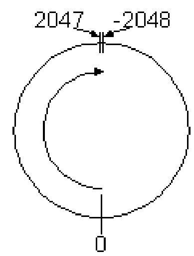
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	In_{n-1} = In Remainder = 0	In_{n-1} = In Remainder = 0
instruction first run	In_{n-1} = In Remainder = 0	In_{n-1} = In Remainder = 0
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example 1: The most common use of the PMUL instruction is in the relative mode of operation. In this mode, the PMUL instruction serves several purposes. First, in the relative mode, the PMUL instruction differentiates the information that it receives at its input from scan to scan. As data is received, the instruction outputs the difference of the input from one scan to the next. This means that if In = 500 at scan “n”, and then In = 600 at scan “n+1”, Out = 100 at scan “n+1.”

Secondly, while in this mode of operation, the PMUL instruction also compensates for “rollover” values of binary data originating from a feedback module. For example, a resolver feedback module may have 12 bits of resolution, represented as a binary value, with sign, ranging from –2048 to 2047. In terms of raw data coming from the feedback module, the rotation of the feedback device might be represented as shown below:



In this example, as the value of the feedback data moves from 2047 to –2048, the effective change in position is equivalent to a jump of 4095 counts in position. In reality, however, this change in position is only 1 part in 4096 in terms of the rotation of the resolver feedback device. By understanding the true word size of the data that is being input from the feedback module, the PMUL instruction views the data in a rotary fashion as shown in the following diagram:



By knowing the word size of the data that is input to this block, the PMUL instruction differentiates an output of 1 count as the input to the block moves from 2047 to –2048, instead of the mathematically calculated 4095.

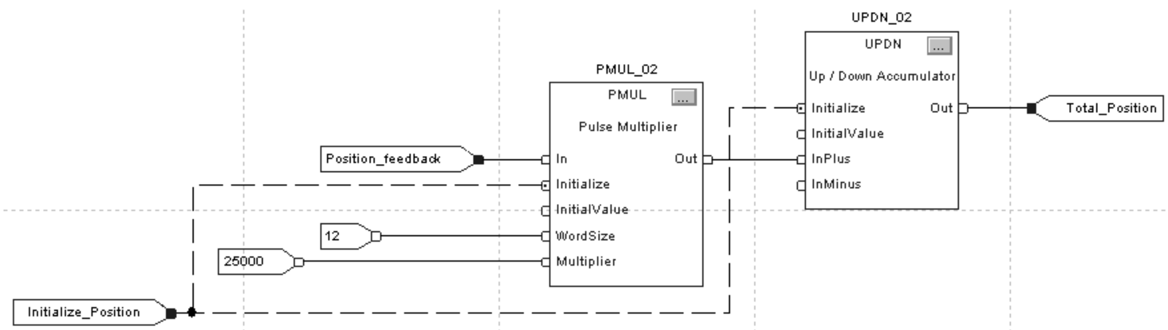
When applying this block, it is important to note that the feedback data should not change by more than ½ the word size from one scan to the next, if rotational direction is to be properly differentiated. In the example above, if the feedback device is moving in a clockwise direction such that at scan 'A' it reads 0 and then scan 'B' it reads –2000, actual change in position is equivalent to +2096 counts in the clockwise direction. However, since these two values are more than ½ the words size, (or more than ½ the rotation of the physical device,) the PMUL instruction calculates that the feedback device rotated in the opposite direction and returns a value of –2000 instead of +2096.

The third attribute of the pulse multiplier block is that it retains the fractional components from one scan to the next of any remainders that exist as a result of the Multiplier/100,000 scaling factor. As each execution of the block is completed, the remainder from the previous scan is added back into the total of the current value so that all counts or "pulses" are ultimately accounted for and no data is lost in the system. The output of the block, Out always yields a whole number in a floating point data type.

Structured Text

```
PMUL_02.In := Position_feedback;
PMUL_02.Initalize := Initialize_Position;
PMUL_02.WordSize := 12;
PMUL_02.Multiplier := 25000;
PMUL(PMUL_02);

UPDN_02.Initialize := Initialize_Position;
UPDN_02.InPlus := PMUL_02.Out;
UPDN(UPDN_02);

Total_Position := UPDN_02.Out;
```

Function Block



Assuming Initial_Position = 0 and Multiplier = 25000 => (25,000/100,000):

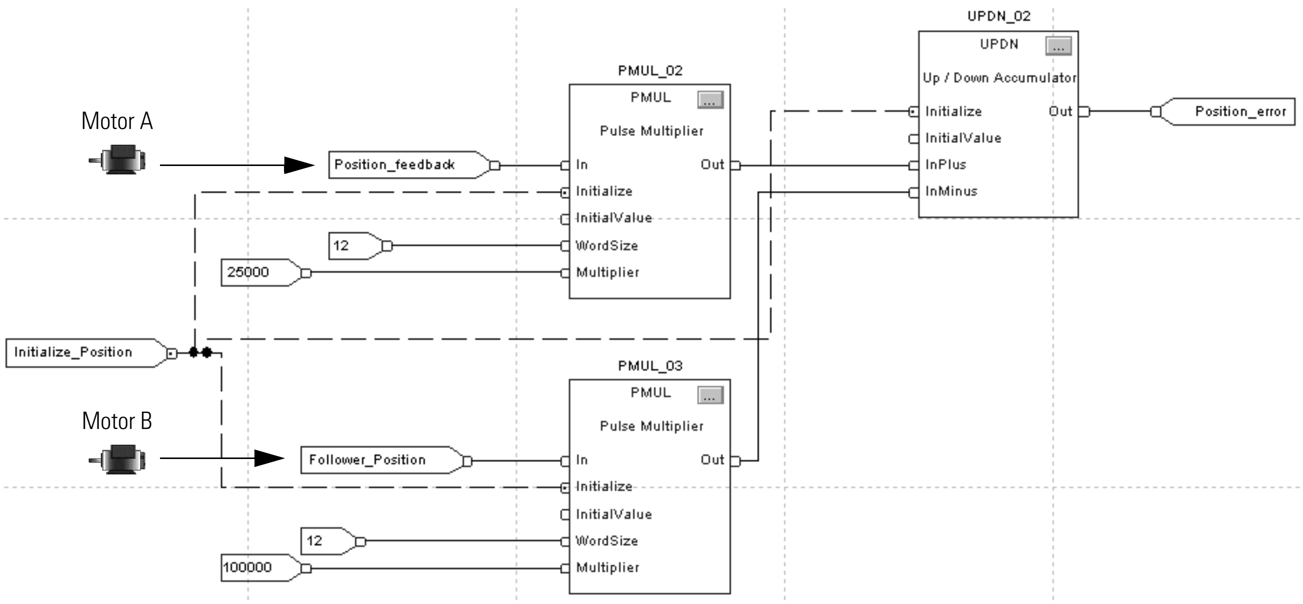
Scan:	Position_Feedback:	PMUL_02.Out:	Total_Position:
n	0	0	0
n + 1	1	0	0
n + 2	2	0	0
n + 3	3	0	0
n + 4	4	1	1
n + 5	5	0	1

Example 2: In this electronic line shaft application, motor A's feedback acts as a master reference which motor B needs to follow. Motor A's feedback is aliased to "Position_feedback." Motor B's feedback is aliased to "Follower_Position." Due to the multipliers of both instructions being a ratio of 1/4, motor B needs to rotate once for every four revolutions of Motor A in order to maintain an accumulated value of zero in the UPDN accumulator. Any value other than zero on the output of the UPDN instruction is viewed as Position_error and can be regulated and driven back out to motor B in order to maintain a phase-lock between the two motors.

Structured Text

```
PMUL_02.In := Position_feedback;
PMUL_02.Initalize := Initialize_Position;
PMUL_02.WordSize := 12;
PMUL_02.Multiplier := 25000;
PMUL(PMUL_02);

PMUL_03.In := Follower_Position;
PMUL_03.Initalize := Initialize_Position;
PMUL_03.WordSize := 12;
PMUL_03.Multiplier := 100000;
PMUL(PMUL_03);

UPDN_02.Initialize := Initialize_Position;
UPDN_02.InPlus := PMUL_02.Out;
UPDN_02.InMinus := PMUL_03.Out;
UPDN(UPDN_02);

Position_error := UPDN_02.Out;
```

Function Block



S-Curve (SCRV)

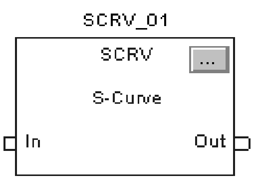
The SCRV instruction performs a ramp function with an added jerk rate. The jerk rate is the maximum rate of change of the rate used to ramp output to input.

Operands:

```
SCRV(SCRV_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
SCRV tag	S_CURVE	structure	SCRV structure



Function Block

Operand:	Type:	Format:	Description:
SCRV tag	S_CURVE	structure	SCRV structure

S_CURVE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	The Initialize input to the instruction. When set, the instruction holds Out = InitialValue Default is cleared.
InitialValue	REAL	Initial value of S-Curve. When Initialize is set, Out = InitialValue. Valid = any float Default = 0.0
AbsAlgRamp	BOOL	Ramp type. If set, the instruction functions as an absolute value ramp. If cleared, the instruction functions as an algebraic ramp. Default is set.
AccelRate	REAL	Acceleration rate in input units per second^2. A value of zero prevents Out from accelerating. When AccelRate < 0, the instruction assumes AccelRate = 0 and sets the appropriate bit in Status. Valid = 0.0 to maximum positive float Default = 0.0
DecelRate	REAL	Deceleration rate in input units per second^2. A value of zero prevents Out from decelerating. When DecelRate < 0, the instruction assumes DecelRate = 0 and sets the appropriate bit in Status. Valid = 0.0 to maximum positive float Default = 0.0

Input Parameter:	Data Type:	Description:
JerkRate	REAL	Jerk rate in input units per second^3. Specifies the maximum rate of change in the acceleration and deceleration rates when ramping output to input. When (JerkRate *DeltaT) ≥ AccelRate and/or DecelRate, the acceleration and deceleration rates are not bounded. In this situation, the instruction behaves as a ramp function. When JerkRate < 0,the instruction assumes JerkRate = 0 and sets the appropriate bit in Status. Valid = 0.0 to maximum positive float Default = 0.0
HoldMode	BOOL	S-Curve hold mode parameter. This parameter is used with the HoldEnable parameter. If HoldMode is set when HoldEnable is set and Rate = 0, the instruction holds Out constant. In this situation, the instruction holds Out as soon as HoldEnable is set, the JerkRate is ignored, and Out produces a "corner" in its profile. If HoldMode is cleared when HoldEnable is set, the instruction uses the JerkRate to bring Out to a constant value. Out is held when Rate = 0. Do not change HoldMode once HoldEnable is set because the instruction will ignore the change. Default is cleared.
HoldEnable	BOOL	S-Curve hold enable parameter. When set, Out is held. When cleared, Out moves from its current value until it equals In. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
S_Mode	BOOL	S_Mode Output. When (Jerk * DeltaT) ≤ Rate and Rate < Accel or Decel, S_Mode is set. Otherwise, S_Mode is cleared.
Out	REAL	The output of the S-Curve instruction. Arithmetic status flags are set for this output.
Rate	REAL	Internal change in the Out in units per second.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.

Output Parameter:	Data Type:	Description:
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
AccelRateInv (Status.1)	BOOL	AccelRate is negative.
DecelRateInv (Status.2)	BOOL	DecelRate is negative.
JerkRateInv (Status.3)	BOOL	JerkRate is negative.
TimingModeInv (Status.27)	BOOL	Invalid timing mode. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS $\lvert$ DeltaT - RTSTime $\rvert$ > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaT (Status.31)	BOOL	Invalid DeltaT value.

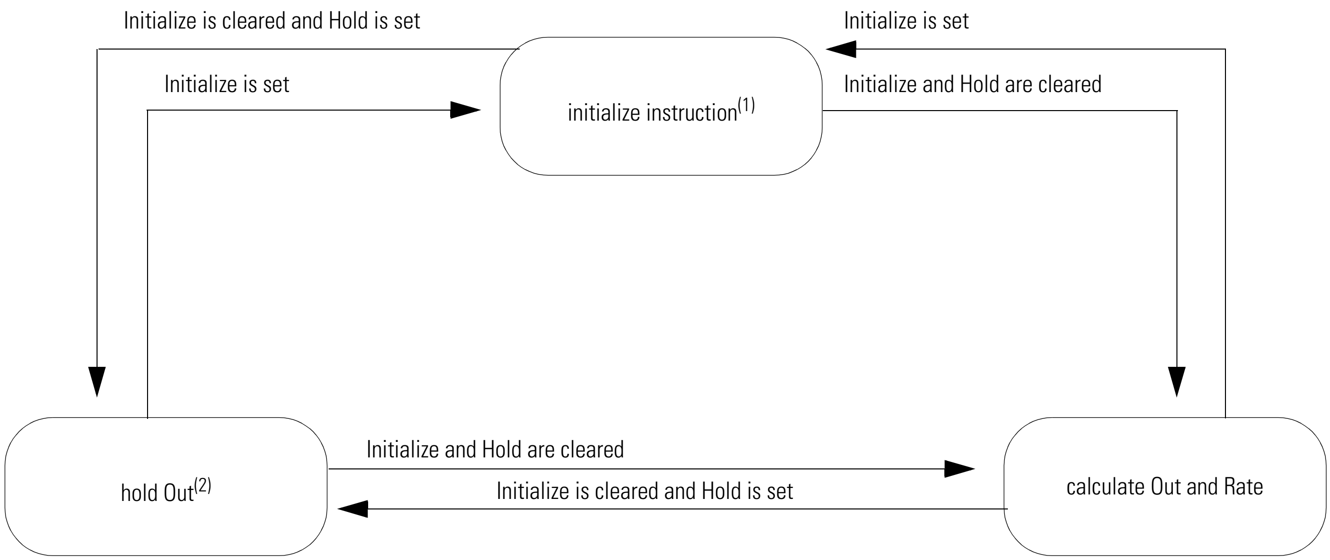
Description:

The primary requirement of the SCRV instruction is to ensure that the rate never changes by more than the specified jerk rate.

You can configure the SCRV instruction to produce an S-Curve profile or a Ramp profile for a step input.

SCRV Profile:	Description:
S-Curve profile	To produce an S-Curve profile, set JerkRate such that (JerkRate ∗ DeltaT) < AccelRate and/or DecelRate. In S-Curve profile mode, the SCRV instruction ensures that the rate never changes more than the specified JerkRate. The algorithm used to produce the S-Curve profile is designed to produce a smooth, symmetric S-Curve for a step input. A trapezoidal integration of Out is incorporated to facilitate this. As a result, changes in Rate will be less than JerkRate during portions of the profile. When a step change occurs on the input, rate is increased to the programmed AccelRate or DecelRate. The AccelRate or DecelRate is maintained until a point at which rate must begin decreasing in order for the output to reach input when rate reaches zero. In some cases, depending on the values of acceleration, deceleration, and jerk, the acceleration rate or deceleration rate might not be reached before the rate must begin decreasing by jerk rate. For very small step changes, the SCRV instruction will not attempt to produce an 'S' profile. In this mode the entire step will be output and Rate will reflect the change in output. This behavior will occur if Out = In and the next step change to In can be output with a rate less than or equal to the programmed JerkRate. The SCRV instruction supports an algebraic ramp and an absolute value ramp. For an algebraic ramp, the acceleration condition is defined by an input that is becoming more positive, and the deceleration condition is defined by an input that is becoming more negative. For an absolute value ramp, the acceleration condition is defined by an input moving away from zero, and the deceleration condition is defined by an input moving towards zero.
Ramp profile	To produce a Ramp profile, set JerkRate such that (JerkRate ∗ DeltaT) ≥ AccelRate and/or DecelRate. In Ramp Profile mode, the SCRV instruction always produces a rate of change equal to the programmed AccelRate or DecelRate until the difference between Out and In requires less then AccelRate or DecelRate to reach endpoint. HoldMode = 0 operates the same as HoldMode = 1. When HoldEnable is set, Out is immediately held and Rate becomes zero.

The following diagram illustrates how the instruction modifies Out.



(1) When Initialize is set, the instruction sets the following:

Out_n = InitialValue

$Out_{n-1} = Out_n$

$Rate_n = 0$

$Rate_{n-1} = 0$

(2) When HoldMode is cleared, Out is moving toward In, and HoldEnable is set, the rate begins decreasing towards zero at the jerk rate. Due to the JerkRate, Out is held at whatever value it had when the rate reached zero. When the Out is finally held constant, it has a value that is different from the value it had the instant that HoldEnable was set.

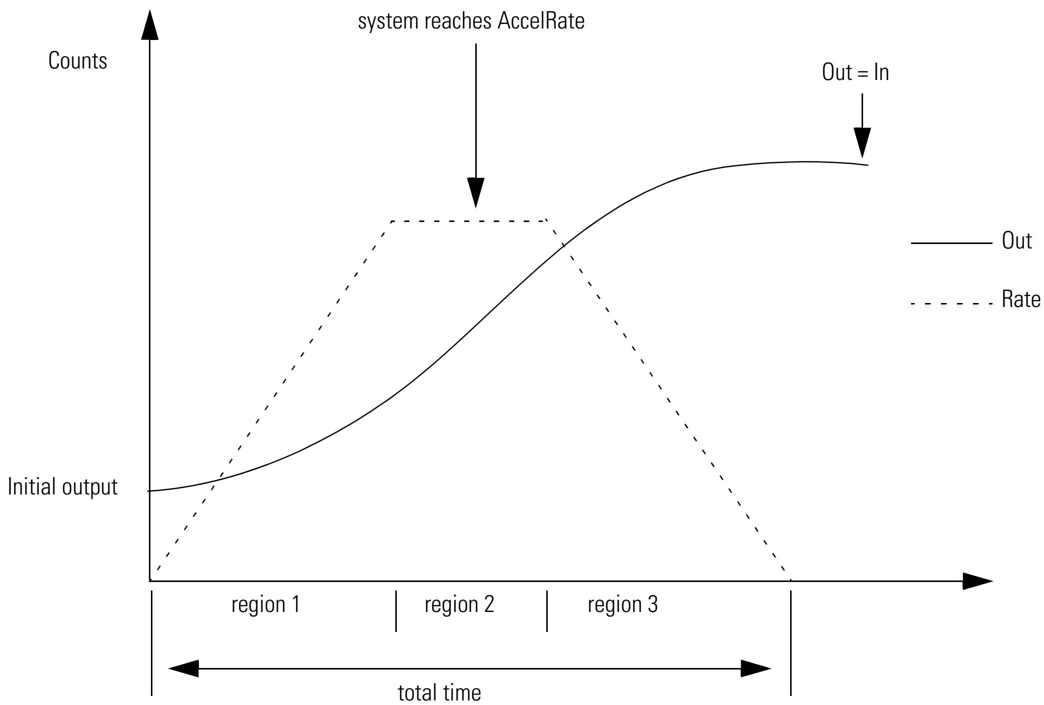
When HoldMode is set, Out is moving toward In, and HoldEnable is set, the rate is immediately set to zero. Out is held at whatever value it had when HoldEnable was set.

Reducing the JerkRate during a transition might cause Out to overshoot the In. If overshoot occurs, it is the result of enforcing the entered JerkRate. You can avoid an overshoot by decreasing JerkRate in small steps while tuning or by changing JerkRate while Out = In (not during a transition).

The time that is required for Out to equal a change in the input is a function of AccelRate, JerkRate, and the difference between In and Out.

Calculating output and rate values

In transition from an initial value to final value, Out goes through three regions. In region 1 and region 3, the rate of change of Out is based on JerkRate. In region 2, the rate of change of Out is based on AccelRate or DecelRate.



The Out is calculated for each region as follows:

$$TotalTime = \frac{FinalOutput - InitialOutput}{AccelRate} + \frac{AccelRate}{JerkRate}$$

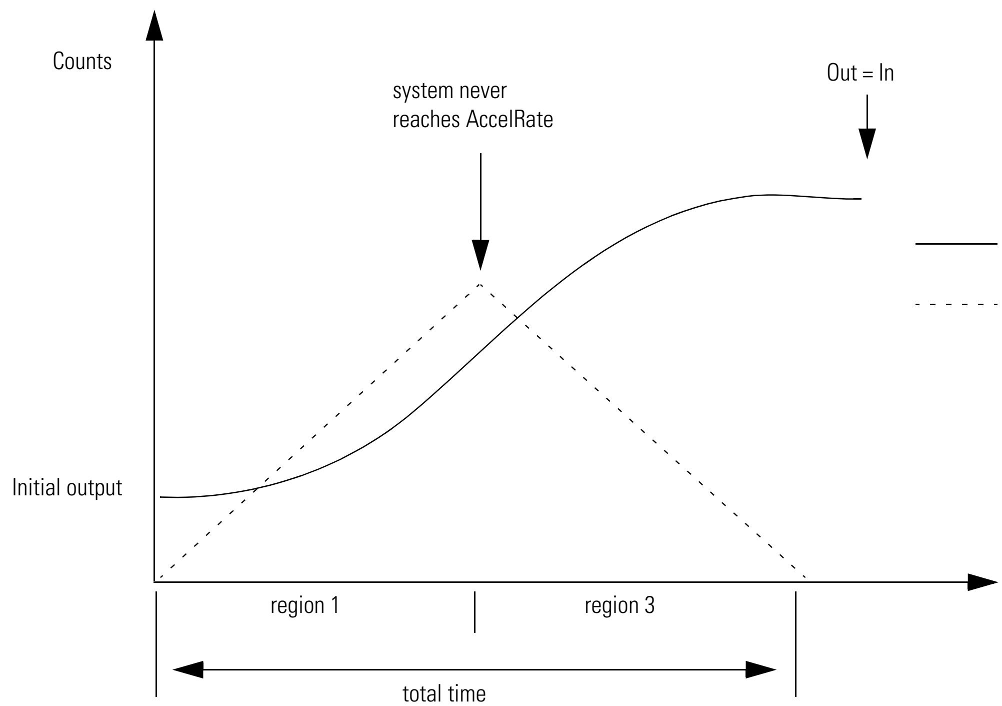
with these equations for each region:

Region:	Equations:
region 1	$Time_1 = \frac{AccelRate}{JerkRate}$ $Y(Time) = InitialOutput + \frac{1}{2}(JerkRate) \times Time^2$
region 2	$Time_2 = \frac{JerkRate \times (FinalOutput - InitialOutput) - AccelRate^2}{JerkRate \times AccelRate}$ $Y(Time) = InitialOutput + (AccelRate \times Time) - \frac{AccelRate^2}{2 \times JerkRate}$
region 3	$Time_3 = \frac{AccelRate}{JerkRate}$ $Y(Time) = FinalOutput - \frac{1}{2}(JerkRate) \times \left(Time - \frac{FinalOutput - InitiaOutput}{AccelRate} - \frac{AccelRate}{JerkRate}\right)^2$

When:

$$|InitialOutput - FinalOutput| < \frac{AccelRate^2}{JerkRate}$$

the SCRV block does not reach the AccelRate or DecelRate. The Out does the following:



where:

$$TotalTime = 2 \times \sqrt{\frac{|InitialOutput - FinalOutput|}{JerkRate}}$$

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

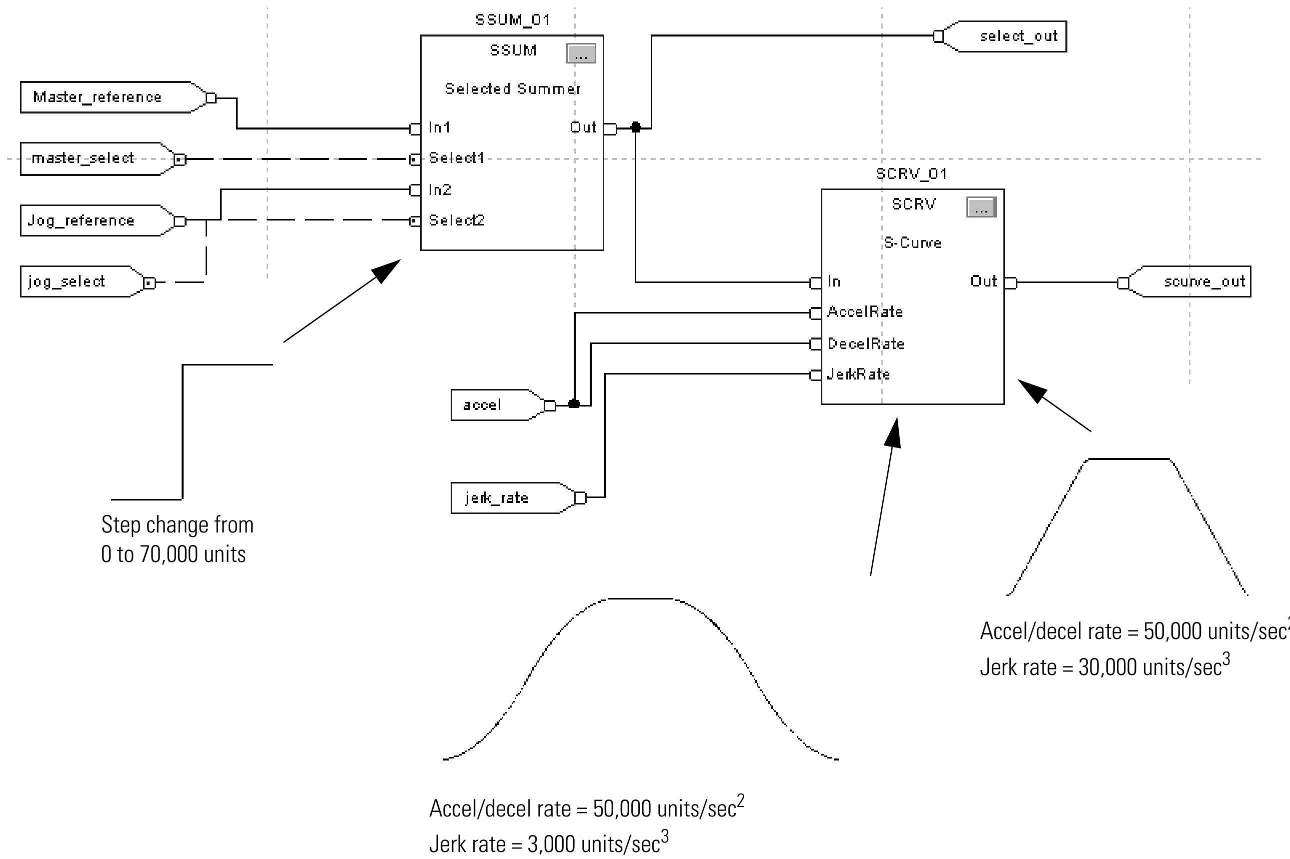
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	Initialize internal variables.	Initialize internal variables.
instruction first run	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: In most coordinated drive applications, a master reference commands line speed for an entire group of drives. As various references are selected, the drives cannot be presented with "step" changes in speed reference because differences in load inertia, motor torque, and tuning would not allow the individual drive sections to react in a coordinated manner. The SCRV instruction is designed to ramp and shape the reference signal to the drive sections so that acceleration, deceleration, and jerk, (derivative of acceleration,) are controlled. This instruction provides a mechanism to allow the reference to the drives to reach the designated reference setpoint in a manner that eliminates excessive forces and excessive impact on connected machinery and equipment.

Structured Text

```
SSUM_01.In1 := Master_reference;
SSUM_01.Select1 := master_select;
SSUM_01.In2 := Jog_reference;
SSUM_01.Select2 := jog_select;
SSUM(SSUM_01);

select_out := SSUM_01.Out;

SCRV_01.In := select_out;
SCRV_01.AccelRate := accel;
SCRV_01.DecelRate := accel;
SCRV_01.JerkRate := jerk_rate;
SCRV(SCRV_01);

scurve_out := SCRV_01.Out
```

Function Block



Second-Order Controller (SOC)

The SOC instruction is designed for use in closed loop control systems in a similar manner to the PI instruction. The SOC instruction provides a gain term, a first order lag, and a second order lead.

Operands:

```
SOC(SOC_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
SOC tag	SEC_ORDER_CONTROLLER	structure	SOC structure

Function Block

Operand:	Type:	Format:	Description:
SOC tag	SEC_ORDER_CONTROLLER	structure	SOC structure

SEC_ORDER_CONTROLLER Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	The instruction initialization command. When set, Out and internal integrator are set equal to the value of InitialValue. Default is cleared.
InitialValue	REAL	The initial value input. When Initialize is set, Out and integrator are set to the value of InitialValue. The value of InitialValue is limited using HighLimit and LowLimit. Valid = any float Default = 0.0
Gain	REAL	The proportional gain for the instruction. If the value is out of range, the instruction limits the value and sets the appropriate bit in Status. Valid = any float > 0.0 Default = minimum positive float
WLag	REAL	First order lag corner frequency in radians/second. If the value is out of range, the instruction limits the value and sets the appropriate bit in Status. Valid = see the Description section below for valid ranges Default = maximum positive float
WLead	REAL	Second order lead corner frequency in radians/second. If the value is out of range, the instruction limits the value and sets the appropriate bit in Status. Valid = see the Description section below for valid ranges Default = 0.0

Input Parameter:	Data Type:	Description:
ZetaLead	REAL	Second order lead damping factor. If the value is out of range, the instruction limits the value and sets the appropriate bit in Status. Valid = 0.0 to 10.0 Default = 0.0
HighLimit	REAL	The high limit value. This is the maximum value for Out. If HighLimit ≤ LowLimit, the instruction sets HighAlarm and LowAlarm, sets the appropriate bit in Status, and sets Out = LowLimit. Valid = LowLimit < HighLimit ≤ maximum positive float Default = maximum positive float
LowLimit	REAL	The low limit value. This is the minimum value for Out. If HighLimit ≤ LowLimit, the instruction sets HighAlarm and LowAlarm, sets the appropriate bit in Status, and sets Out = LowLimit. Valid = maximum negative float ≤ LowLimit < HighLimit Default = maximum negative float
HoldHigh	BOOL	The hold high command. When set, the value of the internal integrator is not allowed to increase in value. Default is cleared.
HoldLow	BOOL	The hold low command. When set, the value of the internal integrator is not allowed to decrease in value. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
HighAlarm	BOOL	The maximum limit alarm indicator. Set when the calculated value for Out ≥ HighLimit and the output is clamped at HighLimit.
LowAlarm	BOOL	The minimum limit alarm indicator. Set when the calculated value for Out ≤ LowLimit and the output is clamped at LowLimit.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
GainInv (Status.1)	BOOL	Gain > maximum or Gain < minimum.
WLagInv (Status.2)	BOOL	WLag > maximum or WLag < minimum.
WLeadInv (Status.3)	BOOL	WLead > maximum or WLead < minimum.
ZetaLeadInv (Status.4)	BOOL	ZetaLead > maximum or ZetaLead < minimum.
HighLowLimsInv (Status.5)	BOOL	HighLimit ≤ LowLimit.
TimingModeInv (Status.27)	BOOL	Invalid timing mode. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaT (Status.31)	BOOL	Invalid DeltaT value.

Description: The SOC instruction provides a gain term, a first order lag, and a second order lead. The frequency of the lag is adjustable and the frequency and damping of the lead is adjustable. The zero pair for the second order lead can be complex (damping < unity) or real (damping Š to unity). The SOC instruction is designed to execute in a task where the scan rate remains constant.

The SOC instruction uses the following Laplace Transfer equation.

$$H(s) = \frac{K\left(\frac{s^2}{\omega_{Lead}^2} + \frac{2 \times \xi_{Lead} \times s}{\omega_{Lead}} + 1\right)}{s\left(\frac{s}{\omega_{Lag}} + 1\right)}$$

Parameter limitations

The following SOC parameters have these limits on valid values.

Parameter:	Limit:
WLead	$LowLimit = \frac{0.00001}{DeltaT}$ $HighLimit = \frac{0.07\pi}{DeltaT}$ where DeltaT is in seconds
WLag	$LowLimit = \frac{0.0000001}{DeltaT}$ $HighLimit = \frac{0.07\pi}{DeltaT}$ where DeltaT is in seconds
ZetaLead	$LowLimit = 0.0$ $HighLimit = 10.0$

Whenever the value computed for the output is invalid or NAN, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. The internal parameters are not updated. In each subsequent scan, the output is computed using the internal parameters from the last scan when the output was valid.

Limiting

The instruction stops wind-up based on state of the Hold inputs.

If:	Then:
HoldHigh is set **and** Integrator > $Integrator_{n-1}$	Integrator = $Integrator_{n-1}$
HoldLow is set **and** Integrator < $Integrator_{n-1}$	Integrator = $Integrator_{n-1}$

The instruction also stops integrator windup based on the HighLimit and LowLimit values.

If:	Then:
Integrator > IntegratorHighLimit	Integrator = IntegratorHighLimit
Integrator < IntegratorLowLimit	Integrator = IntegratorLowLimit

where:

$$IntegratorHighLimit = HighLimit \times \frac{Gain \times WLag}{WLead^2}$$

$$IntegratorLowLimit = LowLimit \times \frac{Gain \times WLag}{WLead^2}$$

The instruction also limits the value of Out based on the HighLimit and LowLimit values.

If:	Then:
HighLimit ≤ LowLimit	Out = LowLimit Integrator = IntegratorLowLimit HighLowLimsInv is set HighAlarm is set LowAlarm is set
Out ≥ HighLimit	Out = HighLimit Integrator = $Integrator_{n-1}$ HighAlarm is set
Out ≤ LowLimit	Out = LowLimit Integrator = $Integrator_{n-1}$ LowAlarm is set

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	The instruction sets the internal parameters and Out = 0. The control algorithm is not executed.	
instruction first run	The instruction sets the internal parameters and Out = 0. The control algorithm is not executed.	
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes and EnableOut is set.	EnableIn is always set. he instruction executes.
postscan	No action taken.	No action taken.

Example: The SOC instruction is a specialized function block that is used in applications where energy is transferred between two sections through a spring-mass system. Typically in these types of applications, the frequency response of the process itself can be characterized as shown in the bode diagram A below:

The SOC instruction implements a first order lag filter followed by a PID controller to implement a transfer function with an integration, a second order zero, (lead,) and a first order pole (lag.) With this instruction, PID tuning is simplified because the regulating terms are arranged so that you have WLead and ZLead as inputs to the SOC instruction, rather than Kp, Ki, and Kd values. The transfer function for the SOC instruction is:

$$H(s) = \frac{K\left(\frac{s^2}{\omega_{Lead}^2} + \frac{2 \times \xi_{Lead} \times s}{\omega_{Lead}} + 1\right)}{s\left(\frac{s}{\omega_{Lag}} + 1\right)}$$

Diagram A: Process characteristics

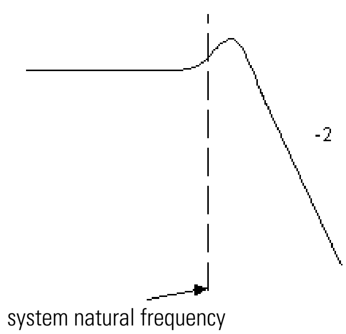
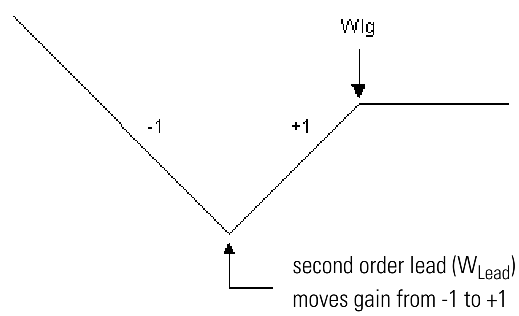
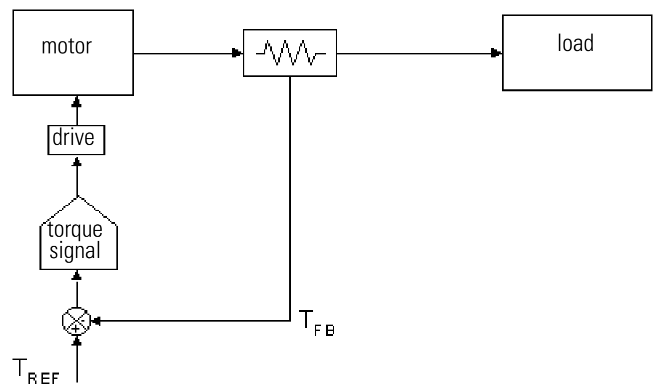


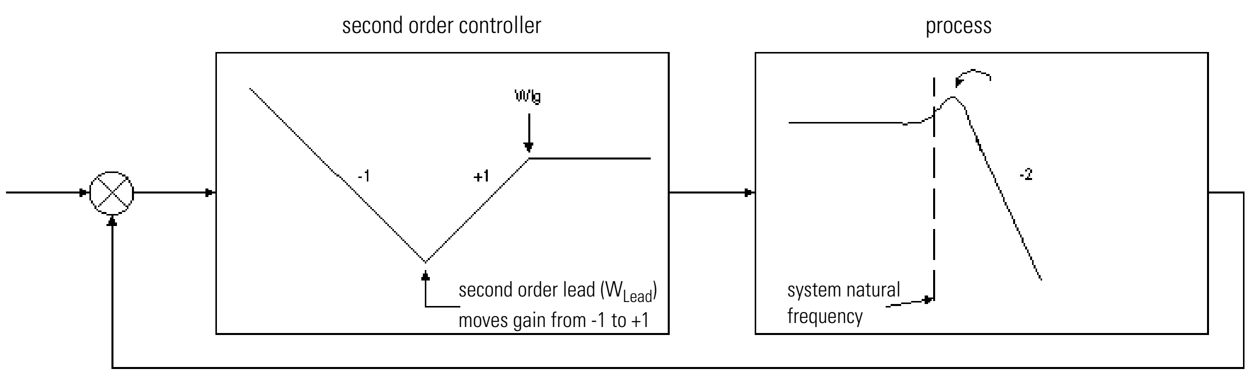
Diagram B: Second order controller



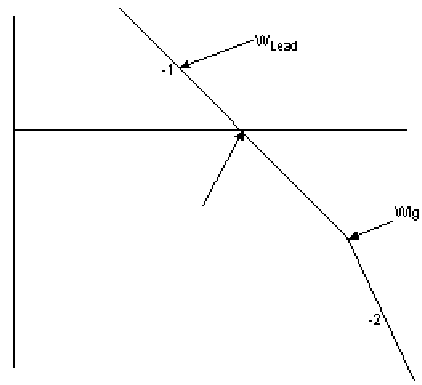
The SOC instruction can be used in a torque or tension regulating application where a load cell or force transducer is used as feedback and the output of the regulating scheme operates directly on the torque (current) minor loop of the drive. In many such applications, the controlled system may be mechanically under-damped and have a natural frequency which is difficult to stabilize as it becomes reflected through the feedback device itself.



Using the SOC instruction, PID tuning is simplified because the regulating terms can be arranged so that you have WLead and ZLead as inputs to the SOC instruction, rather than Kp, Ki, and Kd values. In this manner, the corner frequencies of the controller/regulator are easier to adjust and setup against the real world process. During startup, the natural frequency of the system and the damping factor can be measured empirically or on-site. Afterward, the parameters of the regulator can be adjusted to match the characteristics of the process, allowing more gain and more stable control of the final process.



In the system above, if Wlead is set equal to the system natural frequency, and if Wlag is set substantially above the desired crossover frequency, (> 5 times crossover), the resulting system response would look like the following:



In an actual application, the steps in using and setting up this instruction include:

1. Recognize the type of process that is being controlled. If the system's response to a step function results in a high degree of ringing or can be characterized by the process curve shown above, this block may provide the regulating characteristics required for stable control.

2. Determine the natural frequency of the system/process. This can may be arrived at empirically – or it might be measured on-site. Adjust WLead so that it corresponds with, or is slightly ahead of, the natural frequency of the process itself.

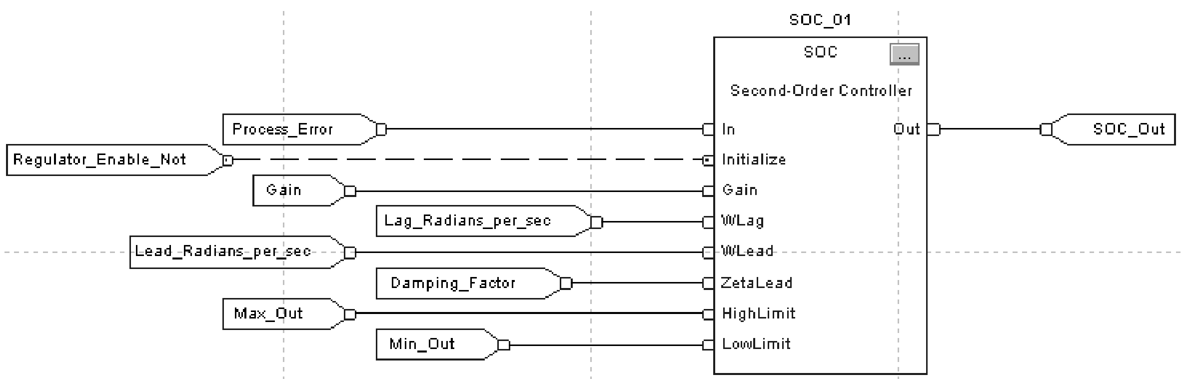
3. Tune damping factor, Zlead, so that it cancels out any of the overshoot in the system.

4. Move WLag out far enough past the system crossover frequency (>5 times) and begin increasing overall Gain to achieve desired system response.

Structured Text

```
SOC_01.In := Process_Error;
SOC_01.Initialize := Regulator_Enable_Not;
SOC_01.Gain := Gain;
SOC_01.WLag := Lag_Radians_per_sec;
SOC_01.WLead := Lead_radians_per_sec;
SOC_01.ZetaLead := Damping_Factor;
SOC_01.HighLimit := Max_Out;
SOC_01.LowLimit := Min_Out;
SOC(SOC_01);

SOC_Out := SOC_01.Out;
```

Function Block



Up/Down Accumulator (UPDN)

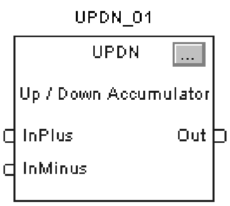
The UPDN instruction adds and subtracts two inputs into an accumulated value.

Operands:

```
UPDN(UPDN_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
UPDN tag	UP_DOWN_ACCUM	structure	UPDN structure



Function Block

Operand:	Type:	Format:	Description:
UPDN tag	UP_DOWN_ACCUM	structure	UPDN structure

UP_DOWN_ACCUM Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
Initialize	BOOL	The initialize input request for the instruction. When Initialize is set, the instruction sets Out and the internal accumulator to InitialValue. Default is cleared.
InitialValue	REAL	The initialize value of the instruction. Valid = any float Default = 0.0
InPlus	REAL	The input added to the accumulator. Valid = any float Default = 0.0
InMinus	REAL	The input subtracted from the accumulator. Valid = any float Default = 0.0
Hold	BOOL	The hold input request for the instruction. When Hold is set and Initialize is cleared, Out is held. Default is cleared.
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Out	REAL	The output of the instruction. Arithmetic status lags are set for this output.

Description: The UPDN instruction follows these algorithms.

Condition:	Action:
Hold is cleared and Initialize is cleared	$AccumValue_n = AccumValue_{n-1} + InPlus - InMinus$ $Out = AccumValue_n$
Hold is set and Initialize is cleared	$AccumValue_n = AccumValue_{n-1}$ $Out = AccumValue_n$
Initialize is set	$AccumValue_n = InitialValue$ $Out = AccumValue_n$

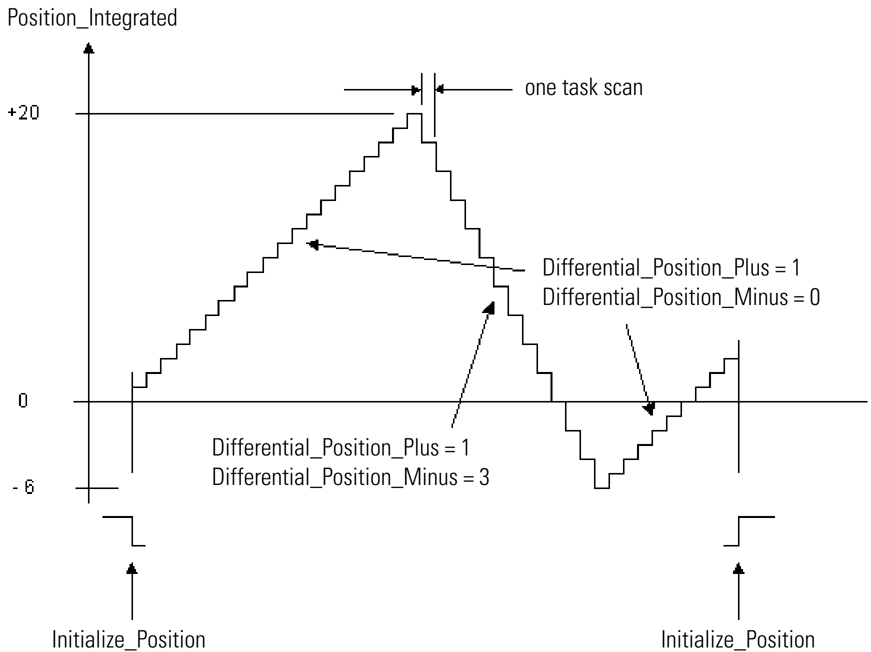
Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	$AccumValue_{n-1} = 0.0$	$AccumValue_{n-1} = 0.0$
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

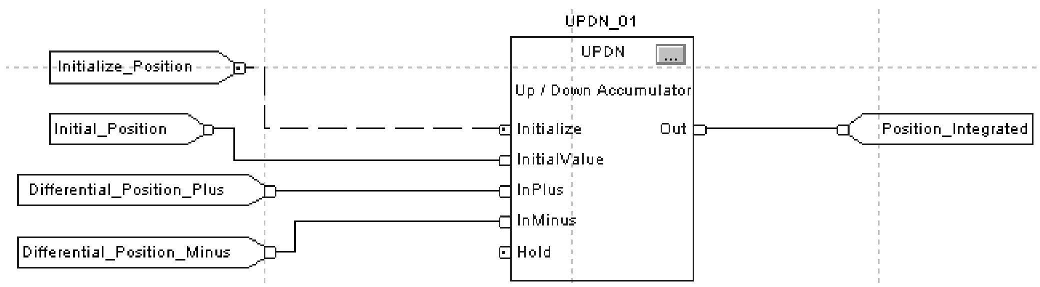
Example: The UPDN instruction integrates counts from one scan to the next. This instruction can be used for simple positioning applications or for other types of applications where simple integration is required to create an accumulated value from a process's differentiated feedback signal. In the example below, Initial_Position is set to zero, while Differential_Position_Plus and Differential_Position_Minus take varying values over a period of time. With this instruction, InPlus and InMinus could also accept negative values.



Structured Text

```
UPDN_01.Initialize := Initialize_Position;
UPDN_01.InitialValue := Initial_Position;
UPDN_01.InPlus := Differential_Position_Plus;
UPDN_01.InMinus := Differential_Position_Minus;
UPDN(UPDN_01);

Position_Integrated := UPDN_01.Out;
```

Function Block



Filter Instructions
(DERV, HPF, LDL2, LPF, NTCH)

Introduction

These filter instructions are available:

If you want to:	Use this instruction:	Available in these languages:	See page:
calculate the amount of change of a signal over time in per-second units.	Derivative (DERV)	structured text function block	3-2
filter input frequencies that are below the cutoff frequency.	High Pass Filter (HPF)	structured text function block	3-6
filter with a pole pair and a zero pair.	Second-Order Lead Lag (LDL2)	structured text function block	3-12
filter input frequencies that are above the cutoff frequency.	Low Pass Filter (LPF)	structured text function block	3-18
filter input frequencies that are at the notch frequency.	Notch Filter (NTCH)	structured text function block	3-24

Derivative (DERV)

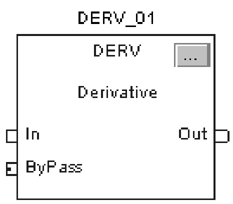
The DERV instruction calculates the amount of change of a signal over time in per-second units.

Operands:

```
DERV(DERV_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
DERV tag	DERIVATIVE	structure	DERV structure



Function Block

Operand:	Type:	Format:	Description:
DERV tag	DERIVATIVE	structure	DERV structure

DERIVATIVE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Gain	REAL	Derivative multiplier Valid = any float Default = 1.0
ByPass	BOOL	Request to bypass the algorithm. When ByPass is set, the instruction sets Out = In. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0

Input Parameter:	Data Type:	Description:
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Description:

The DERV instruction supports a bypass input that lets you stop calculating the derivative and pass the signal directly to the output.

When Bypass is:	The instruction uses this equation:
set	$Out = In_n$ $In_{n-1} = In_n$
cleared **and** DeltaT > 0	$Out = Gain\frac{In_n - In_{n-1}}{DeltaT}$ $In_{n-1} = In_n$ where DeltaT is in seconds

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

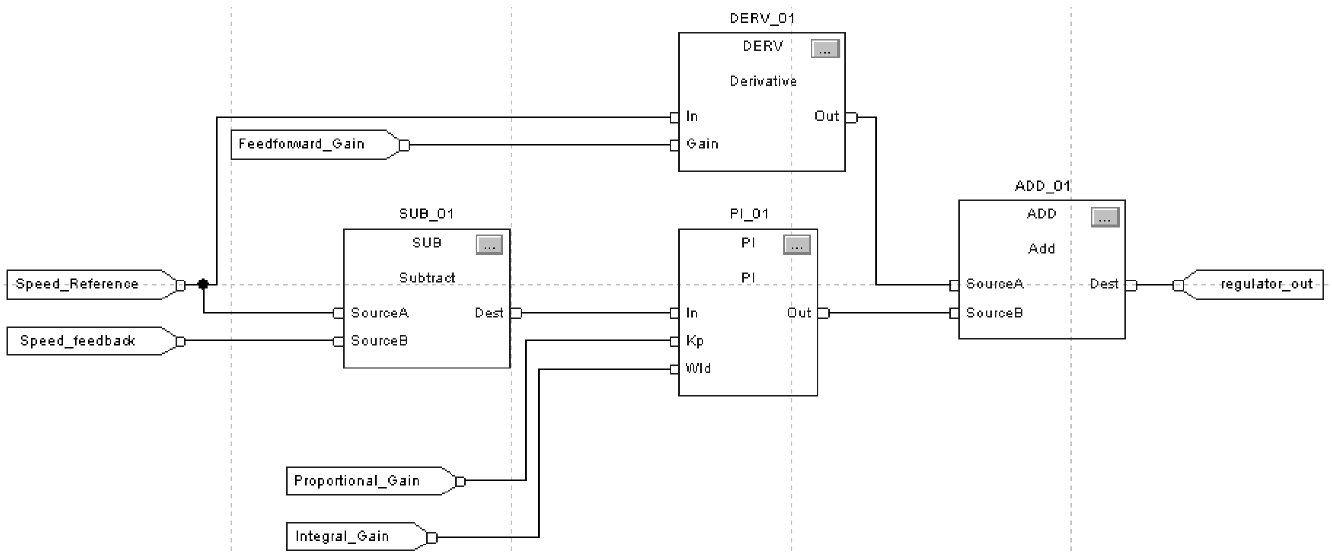
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	$In_{n-1} = In_n$	$In_{n-1} = In_n$
instruction first run	$In_{n-1} = In_n$	$In_{n-1} = In_n$
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The derivative instruction calculates the amount of change of a signal over time in per-second units. This instruction is often used in closed loop control to create a feedforward path in the regulator to compensate for processes that have a high degree of inertia.

Structured Text

```
DERV_01.In := Speed_Reference;
DERV_01.Gain := Feedforward_Gain;
DERV(DERV_01);

PI_01.In := Speed_Reference - Speed_feedback;
PI_01.Kp := Proportional_Gain;
PI_01.Wld := Integral_Gain;
PI(PI_01);

regulator_out := DERV_01.Out + PI_01.Out;
```

Function Block



High Pass Filter (HPF)

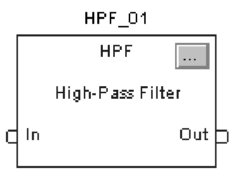
The HPF instruction provides a filter to attenuate input frequencies that are below the cutoff frequency.

Operands:

```
HPF(HPF_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
HPF tag	FILTER_HIGH_PASS	structure	HPF structure



Function Block

Operand:	Type:	Format:	Description:
HPF tag	FILTER_HIGH_PASS	structure	HPF structure

FILER_HIGH_PASS Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	Request to initialize filter control algorithm. When set, the instruction sets Out = In. Default is cleared.
WLead	REAL	The lead frequency in radians/second. If WLead < minimum or WLead > maximum, the instruction sets the appropriate bit in Status and limits WLead. Valid = see Description section below for valid ranges Default = 0.0
Order	REAL	Order of the filter. Order controls the sharpness of the cutoff. If Order is invalid, the instruction sets the appropriate bit in Status and uses Order = 1. Valid = 1 to 3 Default = 1
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0

Input Parameter:	Data Type:	Description:
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
WLeadInv (Status.1)	BOOL	WLead < minimum value or WLead > maximum value.
OrderInv (Status.2)	BOOL	Invalid Order value.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Description: The HPF instruction uses the Order parameter to control the sharpness of the cutoff. The HPF instruction is designed to execute in a task where the scan rate remains constant.

The HPF instruction uses these equation:

When:	The instruction uses this transfer function:
Order = 1	$\frac{s}{s + \omega}$
Order = 2	$\frac{s^2}{s^2 + \sqrt{2} \times s \times \omega + \omega^2}$
Order = 3	$\frac{s^3}{s^3 + (2 \times s^2 \times \omega) + 2 \times s \times \omega^2 + \omega^3}$

with these parameters limits (where DeltaT is in seconds):

Parameter:	Limitations:
WLead first order LowLimit	$\frac{0.0000001}{DeltaT}$
WLead second order LowLimit	$\frac{0.00005}{DeltaT}$
WLead third order LowLimit	$\frac{0.001}{DeltaT}$
HighLimit	$\frac{0.7\pi}{DeltaT}$

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. When the value computed for the output becomes valid, the instruction initializes the internal parameters and sets Out = In.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

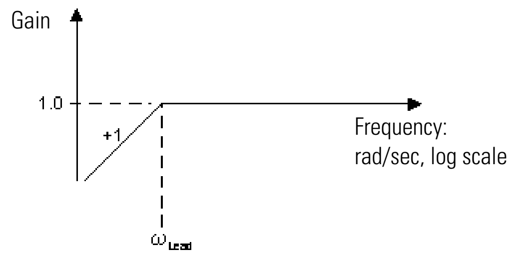
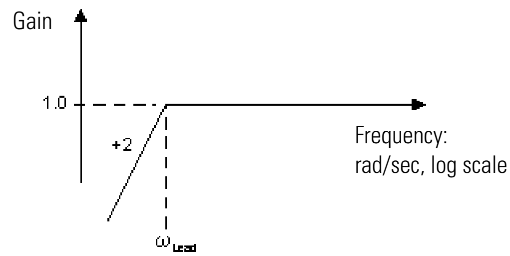
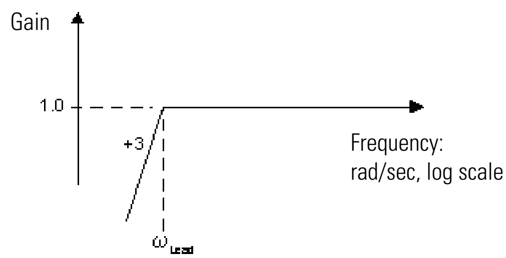
Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	The instruction sets Out = In. The control algorithm is not executed.	The instruction sets Out = In. The control algorithm is not executed.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The HPF instruction attenuates signals that occur below the configured cutoff frequency. This instruction is typically used to filter low frequency "noise" or disturbances that originate from either electrical or mechanical sources. You can select a specific order of the filter to achieve various degrees of attenuation. Note that higher orders increase the execution time for the filter instruction.

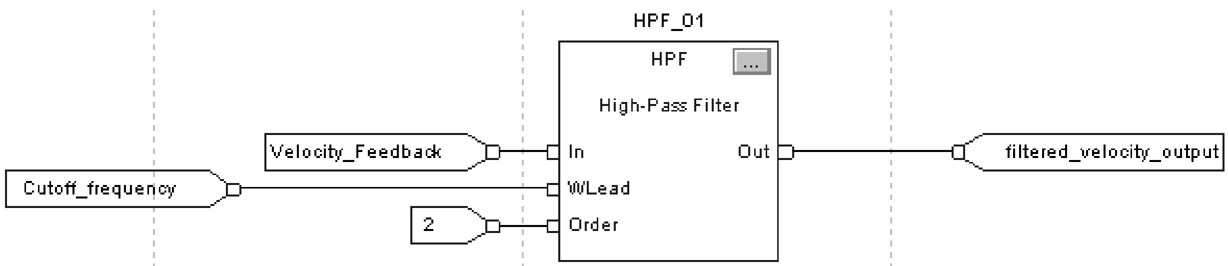
The following graphs illustrate the affect of the various orders of the filter for a given cutoff frequency. For each graph, ideal asymptotic approximations are given with gain and frequency in logarithmic scales. The actual response of the filter approaches these curves but does not exactly match these curves.

Filter:	Graph:
1st order filter	
2nd order filter	
3rd order filter	

Structured Text

```
HPF_01.In := Velocity_Feedback;
HPF_01.WLead := Cutoff_frequency;
HPF_01.Order := 2;

HPF(HPF_01);

filtered_velocity_output := HPF_01.Out
```

Function Block



Second-Order Lead Lag (LDL2)

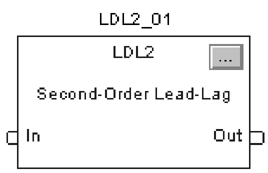
The LDL2 instruction provides a filter with a pole pair and a zero pair. The frequency and damping of the pole and zero pairs are adjustable. The pole or zero pairs can be either complex (damping less than unity) or real (damping greater than or equal to unity).

Operands:

```
LDL2(LDL2_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
LDL2 tag	LEAD_LAG_SEC_ORDER	structure	LDL2 structure



Function Block

Operand:	Type:	Format:	Description:
LDL2 tag	LEAD_LAG_SEC_ORDER	structure	LDL2 structure

LEAD_LAG_SEC_ORDER Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	Request to initialize filter control algorithm. When set, the instruction sets Out = In. Default is cleared.
WLead	REAL	The lead corner frequency in radians/second. If WLead < minimum or WLead > maximum, the instruction sets the appropriate bit in Status and limits WLead. If the WLag:WLead ratio > maximum ratio, the instruction sets the appropriate bit in Status and limits WLag. Valid = see Description section below for valid ranges Default = 0.0
WLag	REAL	The lag corner frequency in radians/second. If WLag < minimum or WLag > maximum, the instruction sets the appropriate bit in Status and limits WLag. If the WLag:WLead ratio > maximum ratio, the instruction sets the appropriate bit in Status and limits WLag. Valid = see Description section below for valid ranges Default = 0.0
ZetaLead	REAL	Second order lead damping factor. Only used when Order = 2. If ZetaLead < minimum or ZetaLead > maximum, the instruction sets the appropriate bit in Status and limits ZetaLead. Valid = 0.0 to 4.0 Default = 0.0

Input Parameter:	Data Type:	Description:
ZetaLag	REAL	Second order lag-damping factor. Only used when Order = 2. If ZetaLag < minimum or ZetaLag > maximum, the instruction sets the appropriate bit in Status and limits ZetaLag. Valid = 0.05 to 4.0 Default = 0.0
Order	REAL	Order of the filter. Selects the first or second order filter algorithm. If invalid, the instruction sets the appropriate bit in Status and uses Order = 2. Valid = 1 to 2 Default = 2
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
WLeadInv (Status.1)	BOOL	WLead < minimum value or WLead > maximum value.
WLagInv (Status.2)	BOOL	WLag < minimum value or WLag > maximum value.
ZetaLeadInv (Status.3)	BOOL	Lead damping factor < minimum value or lead damping factor > maximum value.
ZetaLagInv (Status.4)	BOOL	Lag damping factor < minimum value or lag damping factor > maximum value.
OrderInv (Status.5)	BOOL	Invalid Order value.
WLagRatioInv (Status.6)	BOOL	WLag:WLead ratio greater than maximum value.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).

Output Parameter:	Data Type:	Description:
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Description: The LDL2 instruction filter is used in reference forcing and feedback forcing control methodologies. The LDL2 instruction is designed to execute in a task where the scan rate remains constant.

The LDL2 instruction uses these equations:

When:	The instruction uses this Laplace transfer function:
Order = 1	$$H(s) = \frac{\frac{s}{\omega_{Lead}} + 1}{\frac{s}{\omega_{Lag}} + 1}$$
Order = 2	$$H(s) = \frac{\frac{s^2}{\omega_{Lead}^2} + \frac{2 \times \xi_{Lead} \times s}{\omega_{Lead}} + 1}{\frac{s^2}{\omega_{Lag}^2} + \frac{2 \times \xi_{Lag} \times s}{\omega_{Lag}} + 1}$$ Normalize the filter such that $\omega_{Lead} = 1$ $$H(s) = \frac{s^2 + 2 \times \xi_{Lead} \times s + 1}{\frac{s^2}{\omega_{Lag}^2} + \frac{2 \times \xi_{Lag} \times s}{\omega_{Lag}} + 1}$$

with these parameters limits (where DeltaT is in seconds):

Parameter:	Limitations:
WLead first order LowLimit	$\frac{0.0000001}{DeltaT}$
WLead second order LowLimit	$\frac{0.00005}{DeltaT}$
HighLimit	$\frac{0.7\pi}{DeltaT}$

Parameter:	Limitations:
WLead:WLag ratio	If WLead > WLag, no limitations
	If WLag > WLead: • no minimum limitation for WLag:WLead • first order maximum for WLag:WLead = 40:1 and the instruction limits WLag to enforce this ratio • second order maximum for WLag:WLead = 10:1 and the instruction limits WLag to enforce this ratio
ZetaLead second order only	LowLimit = 0.0 HighLimit = 4.0
ZetaLag second order only	LowLimit = 0.05 HighLimit = 4.0

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. When the value computed for the output becomes valid, the instruction initializes the internal parameters and sets Out = In.

Arithmetic Status Flags:

Arithmetic status flags are set for the Out output.

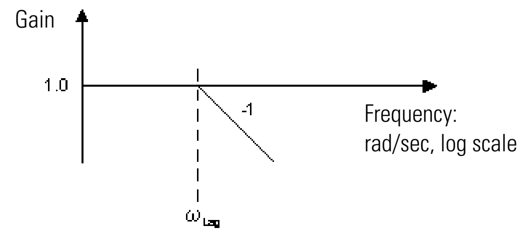
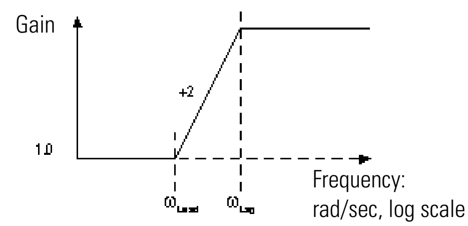
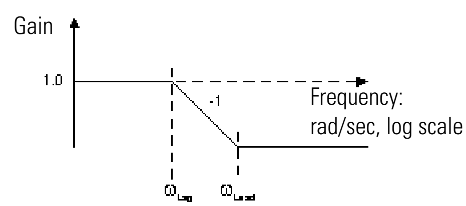
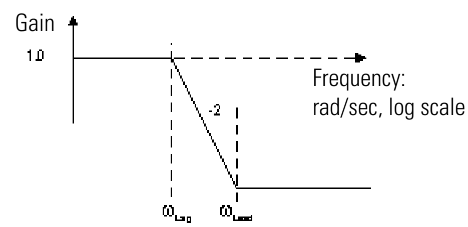
Fault Conditions:

none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	The instruction sets Out = In. The control algorithm is not executed.	The instruction sets Out = In. The control algorithm is not executed.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

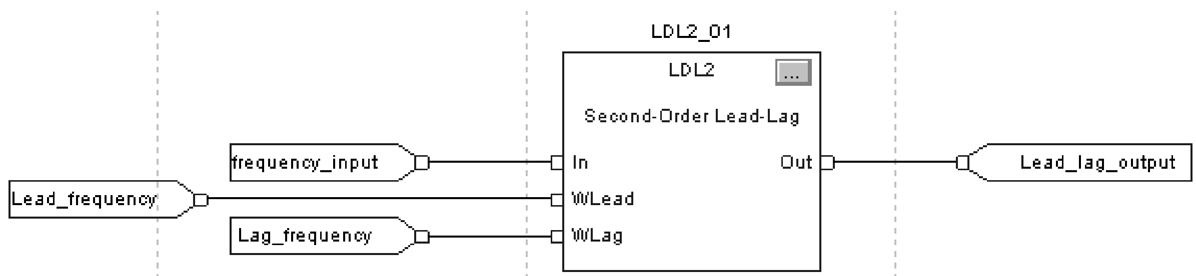
Example: The LDL2 instruction can attenuate between two frequencies or can amplify between two frequencies, depending on how you configure the instruction. Since the Lead and Lag frequencies can be set to values that are larger or smaller than each other, this instruction may behave as a Lead-Lag block, or, as a Lag-Lead block, depending on which frequency is configured first. Note that higher orders increase the execution time for the filter instruction.

Filter:	Graph:
1st order lead-lag ($\omega_{Lead} < \omega_{Lag}$)	
2nd order lead-lag ($\omega_{Lead} < \omega_{Lag}$)	
1st order lead-lag ($\omega_{Lag} < \omega_{Lead}$)	
2nd order lead-lag ($\omega_{Lag} < \omega_{Lead}$)	

Structured Text

```
LDL2_01.In := frequency_input;
LDL2_01.WLead := Lead_frequency;
LDL2_01.WLag := Lag_frequency;

LDL2(LDL2_01);

Lead_lag_output := LDL2_01.Out;
```

Function Block



Low Pass Filter (LPF)

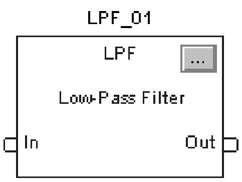
The LPF instruction provides a filter to attenuate input frequencies that are above the cutoff frequency.

Operands:

```
LPF(LPF_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
LPF tag	FILTER_LOW_PASS	structure	LPF structure



Function Block

Operand:	Type:	Format:	Description:
LPF tag	FILTER_LOW_PASS	structure	LPF structure

FILTER_LOW_PASS Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	Request to initialize filter control algorithm. When set, the instruction sets Out = In. Default is cleared.
WLag	REAL	The lag frequency in radians/second. If WLag < minimum or WLag > maximum, the instruction sets the appropriate bit in Status and limits WLag. Valid = see Description section below for valid ranges Default = maximum positive float
Order	REAL	Order of the filter. Order controls the sharpness of the cutoff. If Order is invalid, the instruction sets the appropriate bit in Status and uses Order = 1. Valid = 1 to 3 Default = 1
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0

Input Parameter:	Data Type:	Description:
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

<table>
<tr><th>Output Parameter:</th><th>Data Type:</th><th>Description:</th></tr>
<tr><td>EnableOut</td><td>BOOL</td><td>Enable output.</td></tr>
<tr><td>Out</td><td>REAL</td><td>The calculated output of the algorithm. Arithmetic status flags are set for this output.</td></tr>
<tr><td>DeltaT</td><td>REAL</td><td>Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.</td></tr>
<tr><td>Status</td><td>DINT</td><td>Status of the function block.</td></tr>
<tr><td>InstructFault (Status.0)</td><td>BOOL</td><td>The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.</td></tr>
<tr><td>WLagInv (Status.1)</td><td>BOOL</td><td>WLag < minimum value or WLag > maximum value.</td></tr>
<tr><td>OrderInv (Status.2)</td><td>BOOL</td><td>Invalid Order value.</td></tr>
<tr><td>TimingModeInv (Status.27)</td><td>BOOL</td><td>Invalid TimingMode value.
For more information about timing modes, see appendix Function Block Attributes.</td></tr>
<tr><td>RTSMissed (Status.28)</td><td>BOOL</td><td>Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).</td></tr>
<tr><td>RTSTimeInv (Status.29)</td><td>BOOL</td><td>Invalid RTSTime value.</td></tr>
<tr><td>RTSTimeStampInv (Status.30)</td><td>BOOL</td><td>Invalid RTSTimeStamp value.</td></tr>
<tr><td>DeltaTInv (Status.31)</td><td>BOOL</td><td>Invalid DeltaT value.</td></tr>
</table>

Description: The LPF instruction uses the Order parameter to control the sharpness of the cutoff. The LPF instruction is designed to execute in a task where the scan rate remains constant.

The LPF instruction uses these equations:

When:	The instruction uses this transfer function:
Order = 1	$\frac{\omega}{s + \omega}$
Order = 2	$\frac{\omega^2}{s^2 + \sqrt{2} \times s \times \omega + \omega^2}$
Order = 3	$\frac{\omega^3}{s^3 + (2 \times s^2 \times \omega) + (2 \times s \times \omega^2) \times \omega^3}$

with these parameters limits (where DeltaT is in seconds):

Parameter:	Limitations:
WLag first order LowLimit	$\frac{0.0000001}{DeltaT}$
WLag second order LowLimit	$\frac{0.00005}{DeltaT}$
WLag third order LowLimit	$\frac{0.001}{DeltaT}$
HighLimit	$\frac{0.7\pi}{DeltaT}$

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. When the value computed for the output becomes valid, the instruction initializes the internal parameters and sets Out = In.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

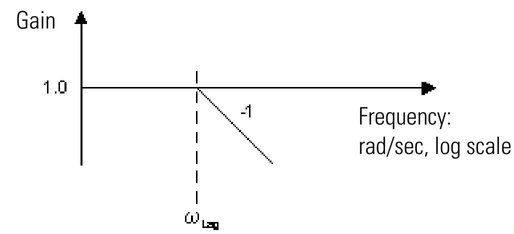
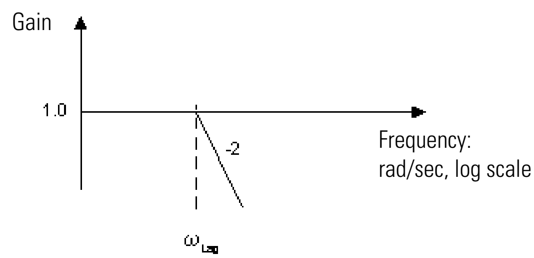
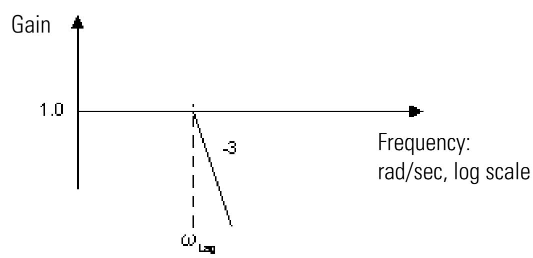
Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	The instruction sets Out = In. The control algorithm is not executed.	The instruction sets Out = In. The control algorithm is not executed.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The LPF instruction attenuates signals that occur above the configured cutoff frequency. This instruction is typically used to filter out high frequency “noise” or disturbances that originate from either electrical or mechanical sources. You can select a specific order of the filter to achieve various degrees of attenuation. Note that higher orders increase the execution time for the instruction.

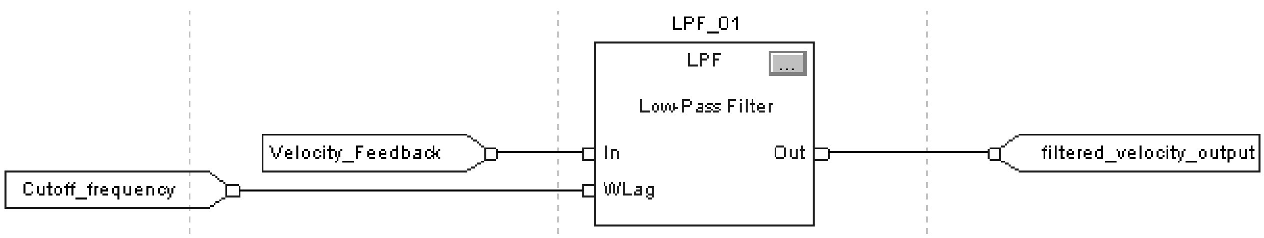
The following graphs illustrate the effect of the various orders of the filter for a given cutoff frequency. For each graph, ideal asymptotic approximations are given with gain and frequency in logarithmic scales. The actual response of the filter approaches these curves but does not exactly match these curves.

Filter:	Graph:
1st order filter	
2nd order filter	
3rd order filter	

Structured Text

```
LPF_01.In := Velocity_Feedback;
LPF_01.WLag := Cutoff_frequency;

LPF(LPF_01);

filtered_velocity_output := LPF_01.Out
```

Function Block



Notch Filter (NTCH)

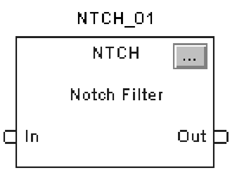
The NTCH instruction provides a filter to attenuate input frequencies that are at the notch frequency.

Operands:

```
NTCH(NTCH_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
NTCH tag	FILTER_NOTCH	structure	NTCH structure



Function Block

Operand:	Type:	Format:	Description:
NTCH tag	FILTER_NOTCH	structure	NTCH structure

FILTER_NOTCH Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Initialize	BOOL	Request to initialize filter control algorithm. When set, the instruction sets Out = In. Default is cleared.
WNotch	REAL	The filter center frequency in radians/second. If WNotch < minimum or WNotch > maximum, the instruction sets the appropriate bit in status and limits WNotch. Valid = see Description section below for valid ranges Default = maximum positive float
QFactor	REAL	Controls the width and depth ratio. Set QFactor = 1 / (2*desired damping factor). If QFactor < minimum or QFactor > maximum value, the instruction sets the appropriate bit in Status and limits QFactor. Valid = 0.5 to 100.0 Default = 0.5
Order	REAL	Order of the filter. Order controls the sharpness of the cutoff. If Order is invalid, the instruction sets the appropriate bit in Status and uses Order = 2. Valid = 2 or 4 Default = 2

Input Parameter:	Data Type:	Description:
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
WNotchInv (Status.1)	BOOL	WNotch < minimum or WNotch > maximum.
QFactorInv (Status.2)	BOOL	QFactor < minimum or QFactor > maximum.
OrderInv (Status.3)	BOOL	Invalid Order value.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value. For more information about timing modes, see appendix Function Block Attributes.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Description: The NTCH instruction uses the Order parameter to control the sharpness of the cutoff. The QFactor parameter controls the width and the depth ratio of the notch. The NTCH instruction is designed to execute in a task where the scan rate remains constant.

The NTCH instruction uses this equation:

$$\frac{(s^2 + \omega^2)^i}{\left(s^2 + s \times \frac{\omega}{Q} + \omega^2\right)^i}$$

where i is the Order operator with these parameters limits (where DeltaT is in seconds):

Parameter:	Limitations:
WNotch second order LowLimit	$\frac{0.0000001}{DeltaT}$
WNotch fourth order LowLimit	$\frac{0.001}{DeltaT}$
HighLimit	$\frac{0.7\pi}{DeltaT}$
QFactor	LowLimit = 0.5 HighLimit = 100.0

Whenever the value computed for the output is invalid, NAN, or ±INF, the instruction sets Out = the invalid value and sets the arithmetic overflow status flag. When the value computed for the output becomes valid, the instruction initializes the internal parameters and sets Out = In.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

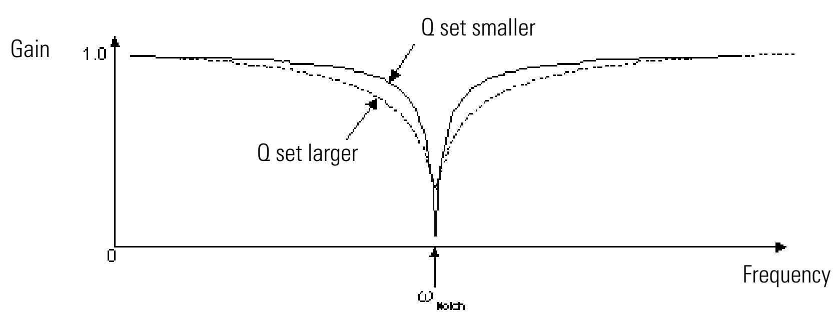
Fault Conditions: none

Execution:

Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	The instruction sets Out = In. The control algorithm is not executed.	The instruction sets Out = In. The control algorithm is not executed.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The NTCH instruction attenuates a specific resonance frequency. Typically, these resonance frequencies are directly in the range of response being regulated by the closed loop control system. Often, they are generated by loose mechanical linkages that cause backlash and vibration in the system. Although the best solution is to correct the mechanical compliance in the machinery, the notch filter can be used to soften the effects of these signals in the closed loop regulating scheme.

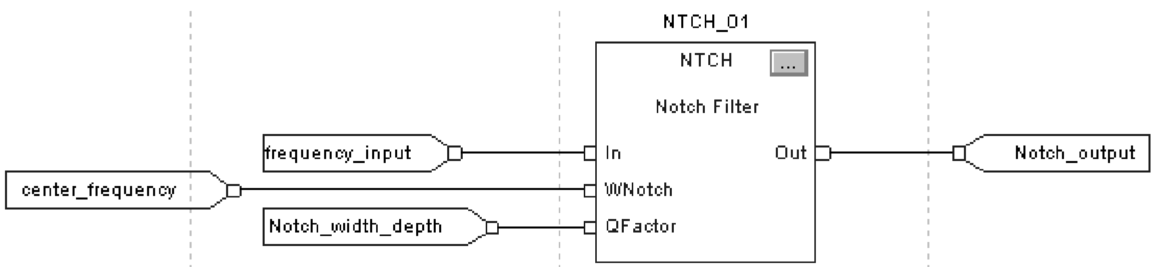
The following diagram shows the ideal gain curve over a frequency range for a specific center frequency and Q factor. As Q increases, the notch becomes wider and shallower. A Q decreases, the notch becomes deeper and narrower. The instruction may be set for an order of 2 or an order of 4. Higher orders take more execution time.



Structured Text

```
NTCH_01.In := frequency_input;
NTCH_01.WNotch := center_frequency;
NTCH_01.QFactor := Notch_width_depth;
NTCH(NTCH_01);

Notch_output := NTCH_01.Out;
```

Function Block



Select/Limit Instructions
(ESEL, HLL, MUX, RLIM, SEL, SNEG, SSUM)

Introduction

These select/limit instructions are available:

If you want to:	Use this instruction:	Available in these languages:	See page:
select one of as many as six inputs.	Enhanced Select (ESEL)	structured text function block	4-2
limit an analog input between two values.	High/Low Limit (HLL)	structured text function block	4-9
select one of eight inputs.	Multiplexer (MUX)	function block	4-12
limit the amount of change of a signal over time.	Rate Limiter (RLIM)	structured text function block	4-15
select one of two inputs.	Select (SEL)	function block	4-19
select between the input value and the negative of the input value.	Selected Negate (SNEG)	structured text function block	4-21
select real inputs to be summed.	Selected Summer (SSUM)	structured text function block	4-23

Enhanced Select (ESEL)

The ESEL instruction lets you select one of as many as six inputs. Selection options include:

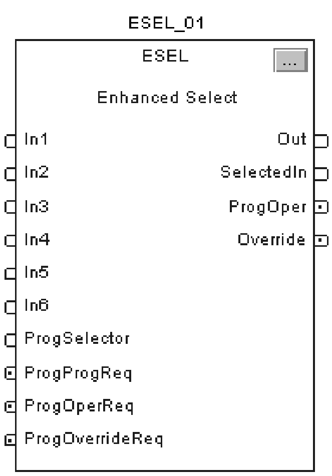
- manual select (either by operator or by program)
- high select
- low select
- median select
- average (mean) select

Operands:

```
ESEL(ESEL_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
ESEL tag	SELECT_ENHANCED	structure	ESEL structure



Function Block

Operand:	Type:	Format:	Description:
ESEL tag	SELECT_ENHANCED	structure	ESEL structure

SELECT_ENHANCED Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In1	REAL	The first analog signal input to the instruction. Valid = any float Default = 0.0
In2	REAL	The second analog signal input to the instruction. Valid = any float Default = 0.0
In3	REAL	The third analog signal input to the instruction. Valid = any float Default = 0.0

Input Parameter:	Data Type:	Description:
In4	REAL	The fourth analog signal input to the instruction. Valid = any float Default = 0.0
In5	REAL	The fifth analog signal input to the instruction. Valid = any float Default = 0.0
In6	REAL	The sixth analog signal input to the instruction. Valid = any float Default = 0.0
In1Fault	BOOL	Bad health indicator for In1. If In1 is read from an analog input, then In1Fault is normally controlled by the fault status on the analog input. If all the In_nFault inputs are set, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Out is not updated Default = cleared.
In2Fault	BOOL	Bad health indicator for In2. If In2 is read from an analog input, then In2Fault is normally controlled by the fault status on the analog input. If all the In_nFault inputs are set, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Out is not updated Default = cleared.
In3Fault	BOOL	Bad health indicator for In3. If In3 is read from an analog input, then In3Fault is normally controlled by the fault status on the analog input. If all the In_nFault inputs are set, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Out is not updated Default = cleared.
In4Fault	BOOL	Bad health indicator for In4. If In4 is read from an analog input, then In4Fault is normally controlled by the fault status on the analog input. If all the In_nFault inputs are set, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Out is not updated Default = cleared.
In5Fault	BOOL	Bad health indicator for In5. If In5 is read from an analog input, then In5Fault is normally controlled by the fault status on the analog input. If all the In_nFault inputs are set, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Out is not updated Default = cleared.
In6Fault	BOOL	Bad health indicator for In6. If In6 is read from an analog input, then In6Fault is normally controlled by the fault status on the analog input. If all the In_nFault inputs are set, the instruction sets the appropriate bit in Status, the control algorithm is not executed, and Out is not updated Default = cleared.
InsUsed	DINT	Number of inputs used. This defines the number of inputs the instruction uses. The instruction considers only In1 through $In_{InsUsed}$ in high select, low select, median select, and average select modes. If this value is invalid, the instruction sets the appropriate bit in Status. The instruction does not update Out if InsUsed is invalid and if the instruction is not in manual select mode and if Override is cleared. Valid = 1 to 6 Default = 1

Input Parameter:	Data Type:	Description:
SelectorMode	DINT	Selector mode input. This value determines the action of the instruction. **Value:** **Description:** 0 manual select 1 high select 2 low select 3 median select 4 average select If this value is invalid, the instruction sets the appropriate bit in Status and does not update Out. Valid = 0 to 4 Default = 0
ProgSelector	DINT	Program selector input. When the selector mode is manual select and the instruction is in Program control, ProgSelector determines which input (In1-In6) to move into Out. If ProgSelector = 0, the instruction does not update Out. If ProgSelector is invalid, the instruction sets the appropriate bit in Status. If invalid and the instruction is in Program control, and the selector mode is manual select or Override is set, the instruction does not update Out. Valid = 0 to 6 Default = 0
OperSelector	DINT	Operator selector input. When the selector mode is manual select and the instruction is in Operator control, OperSelector determines which input (In1-In6) to move into Out. If OperSelector = 0, the instruction does not update Out. If OperSelector is invalid, the instruction sets the appropriate bit in Status. If invalid and the instruction is in Operator control, and the selector mode is manual select or Override is set, the instruction does not update Out. Valid = 0 to 6 Default = 0
ProgProgReq	BOOL	Program program request. Set by the user program to request Program control. Ignored if ProgOperReq is set. Holding this set and ProgOperReq cleared locks the instruction into Program control. Default is cleared.
ProgOperReq	BOOL	Program operator request. Set by the user program to request Operator control. Holding this set locks the instruction into Operator control. Default is cleared.
ProgOverrideReq	BOOL	Program override request. Set by the user program to request the device to enter Override mode. Ignored if ProgOper is cleared. In Override mode, the instruction will act as a manual select. Default is cleared.
OperProgReq	BOOL	Operator program request. Set by the operator interface to request Program control. The instruction clears this input. Default is cleared.
OperOperReq	BOOL	Operator operator request. Set by the operator interface to request Operator control. The instruction clears this input. Default is cleared.
ProgValueReset	BOOL	Reset program control values. When set, all the program request inputs are cleared each execution of the instruction. Default is cleared.

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
SelectedIn	DINT	Number of input selected. The instruction uses this value to display the number of the input currently being placed into the output. If the selector mode is average select, the instruction sets SelectedIn = 0.
ProgOper	BOOL	Program/Operator control indicator. Set when in Program control. Cleared when in Operator control.
Override	BOOL	Override mode. Set when the instruction is in Override mode.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
InsFaulted (Status.1)	BOOL	In_nFault inputs for all the used In_n inputs are set.
InsUsedInv (Status.2)	BOOL	Invalid InsUsed value.
SelectorModeInv (Status.3)	BOOL	Invalid SelectorMode value.
ProgSelectorInv (Status.4)	BOOL	Invalid ProgSelector value.
OperSelectorInv (Status.5)	BOOL	Invalid OperSelector value.

Description:

The ESEL instruction operates as follows:

Condition:	Action:
SelectorMode = 0 (manual select) **or** Override is set, ProgOper is cleared, and OperSelector $\neq 0$	Out = In[OperSelector] SelectedIn = OperSelector
SelectorMode = 0 (manual select) **or** Override is set, ProgOper is set, and ProgSelector $\neq 0$	Out = In[ProgSelector] SelectedIn = ProgSelector
SelectorMode = 1 (high select) **and** Override is cleared	Out = maximum of In[InsUsed] SelectedIn = index to the maximum input value
SelectorMode = 2 (low select) **and** Override is cleared	Out = minimum of In[InsUsed] SelectedIn = index to the minimum input value
SelectorMode = 3 (median select) **and** Override is cleared	Out = median of In[InsUsed] SelectedIn = index to the median input value
SelectorMode = 4 (average select) **and** Override is cleared	Out = average of In[InsUsed] SelectedIn = 0

For SelectorMode 1 through 4, a bad health indication for any of the inputs causes that bad input to be disregarded in the selection. For example, if SelectorMode = 1 (high select) and if In6 had the highest value but had bad health, then the next highest input with good health is moved into the output.

For high or low select mode, if two inputs are equal and are high or low, the instruction outputs the first found input. For median select mode, the median value always represents a value selected from the available inputs. If more than one value could be the median, the instruction outputs the first found input.

Monitoring the ESEL instruction

There is an operator faceplate available for the ESEL instruction. For more information, see appendix Function Block Faceplate Controls.

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

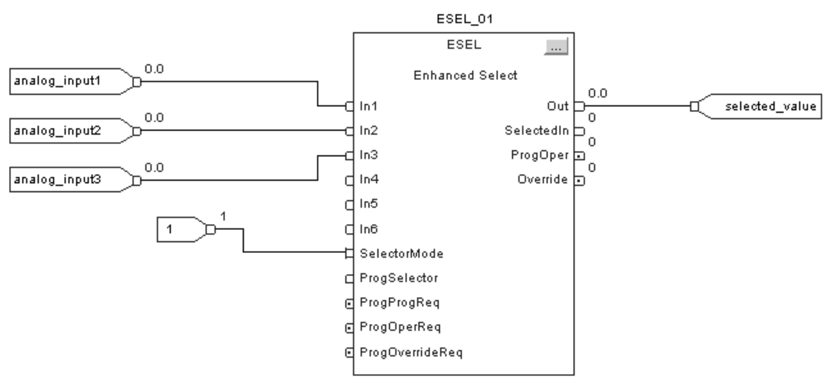
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	All the operator request inputs are cleared. If ProgValueReset is set, all the program request inputs are cleared.	All the operator request inputs are cleared. If ProgValueReset is set, all the program request inputs are cleared.
instruction first run	The instruction is set to Operator control.	The instruction is set to Operator control.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: This ESEL instruction selects In1, In2, or In3, based on the SelectorMode. In this example, SelectorMode = 1, which means high select. The instruction determines which input value is the greatest and sets Out = greatest In.

Structured Text

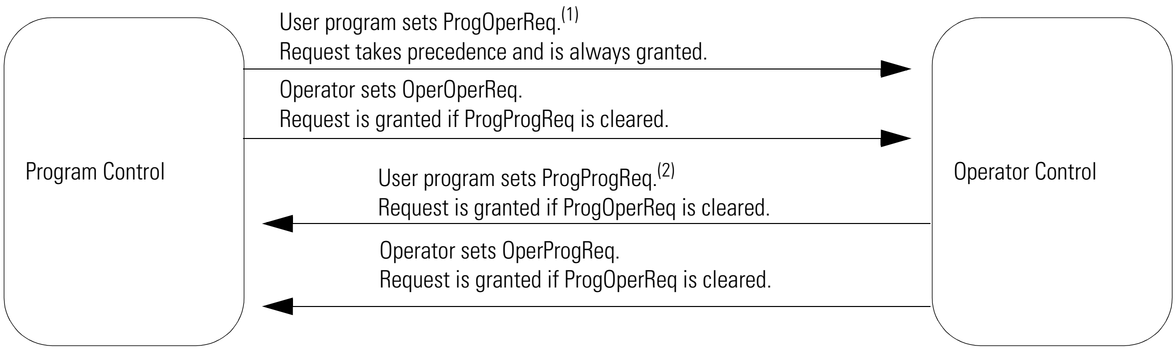
```
ESEL_01.In1 := analog_input1;
ESEL_01.In2 := analog_input2;
ESEL_01.In3 := analog_input3;
ESEL_01.SelectorMode := 1;
ESEL(ESEL_01);

selected_value := ESEL_01.Out;
```

Function Block



Switching between Program control and Operator control

The following diagram shows how the ESEL instruction changes between Program control and Operator control.



(1) You can lock the instruction in Operator control mode by leaving ProgOperReq set.

(2) You can lock the instruction in Program control mode by leaving ProgProgReq set while ProgOperReq is cleared.

For more information on program and operator control, see page B-13.

High/Low Limit (HLL)

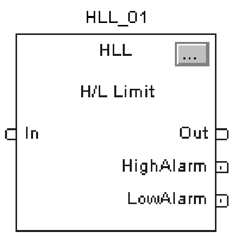
The HLL instruction limits an analog input between two values. You can select high/low, high, or low limits.

Operands:

```
HLL(HLL_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
HLL tag	HL_LIMIT	structure	HLL structure



Function Block

Operand:	Type:	Format:	Description:
HLL tag	HL_LIMIT	structure	HLL structure

HL_LIMIT Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
HighLimit	REAL	The high limit for the Input. If HighLimit ≤ LowLimit, the instruction sets the appropriate bit in Status and sets Out = LowLimit. Valid = HighLimit > LowLimit Default = maximum positive float
LowLimit	REAL	The low limit for the Input. If HighLimit ≤ LowLimit, the instruction sets the appropriate bit in Status and sets Out = LowLimit. Valid = LowLimit < HighLimit Default = maximum negative float
SelectLimit	DINT	Select limit input. This input has three settings: **Value:** **Description:** 0 use both limits 1 use high limit 2 use low limit If SelectLimit is invalid, the instruction assumes SelectLimit = 0 and sets the appropriate bit in Status. Valid = 0 to 2 Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
HighAlarm	BOOL	The high alarm indicator. Set when In ≥ HighLimit.
LowAlarm	BOOL	The low alarm indicator. Set when In ≤ LowLimit.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
LimitsInv (Status.1)	BOOL	HighLimit ≤ LowLimit.
SelectLimitInv (Status.2)	BOOL	The value of SelectLimit is not a 0, 1, or 2.

Description: The HLL instruction determines the value of the Out using these rules:

Selection:	Condition:	Action:
SelectLimit = 0 (use high and low limits)	In < HighLimit and In > LowLimit	Out = In
	In ≥ HighLimit	Out = HighLimit HighAlarm is set
	In ≤ LowLimit	Out = LowLimit LowAlarm is set
	HighLimit ≤ LowLimit	Out = LowLimit HighAlarm is set LowAlarm is set LimitsInv is set
SelectLimit = 1 (use high limit only)	In < HighLimit	Out = In
	In ≥ HighLimit	Out = HighLimit HighAlarm is set
SelectLimit = 2 (use low limit only)	In > LowLimit	Out = In
	In ≤ LowLimit	Out = LowLimit LowAlarm is set

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

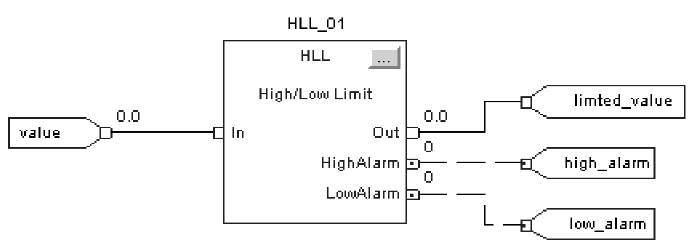
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: This HLL instruction limits In between two values and sets HighAlarm or LowAlarm, if needed. When In is outside the limits, the instruction sets Out = limited value of In

Structured Text

```
HLL_01.In := value;
HLL(HLL_01);

limited_value := HLL_01.Out;
high_alarm := HLL_01.HighAlarm;
low_alarm := HLL_01.LowAlarm;
```

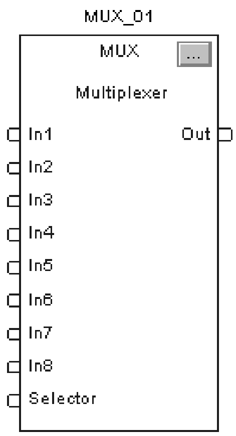
Function Block



Multiplexer (MUX)

The MUX instruction selects one of eight inputs based on the selector input.

Operands:



Function Block

Operand:	Type:	Format:	Description:
block tag	MULTIPLEXER	structure	MUX structure

MULTIPLEXER Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	Enable input. If cleared, the instruction does not execute and outputs are not updated. Default is set.
In1	REAL	The first analog signal input to the instruction. Valid = any float Default = 0.0
In2	REAL	The second analog signal input to the instruction. Valid = any float Default = 0.0
In3	REAL	The third analog signal input to the instruction. Valid = any float Default = 0.0
In4	REAL	The fourth analog signal input to the instruction. Valid = any float Default = 0.0
In5	REAL	The fifth analog signal input to the instruction. Valid = any float Default = 0.0
In6	REAL	The sixth analog signal input to the instruction. Valid = any float Default = 0.0

Input Parameter:	Data Type:	Description:
In7	REAL	The seventh analog signal input to the instruction. Valid = any float Default = 0.0
In8	REAL	The eighth analog signal input to the instruction. Valid = any float Default = 0.0
Selector	DINT	The selector input to the instruction. This input determines which of the inputs (1-8) is moved into Out. If this value is invalid (which includes 0), the instruction sets the appropriate bit in Status and holds Out at its current value. Valid = 1 to 8 Default = 0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The selected output of the algorithm. Arithmetic status flags are set for this output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
SelectorInv (Status.1)	BOOL	Invalid Selector value.

Description:

Based on the Selector value, the MUX instruction sets Out equal to one of eight inputs.

Arithmetic Status Flags:

Arithmetic status flags are set for the Out output.

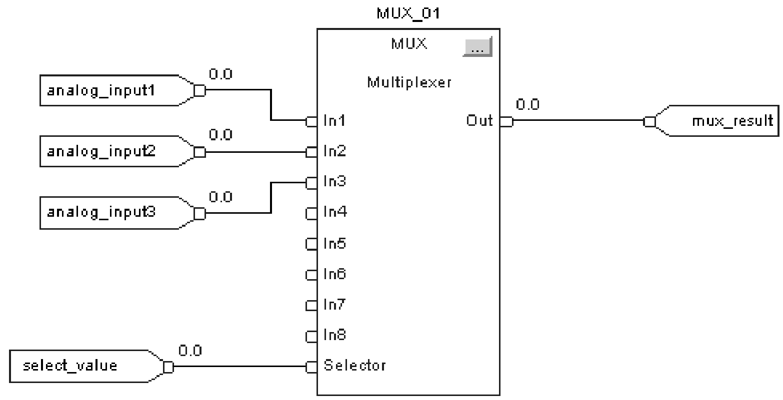
Fault Conditions:

none

Execution:

Condition:	Function Block Action:
prescan	No action taken.
instruction first scan	Internal parameters are cleared.
instruction first run	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.
EnableIn is set	The instruction executes. EnableOut is set.
postscan	No action taken.

Example: This MUX instruction selects In1, In2, or In3, based on the Selector. The instruction sets Out = In_n. For example, if select_value = 2, the instruction sets Out = analog_input2.



Rate Limiter (RLIM)

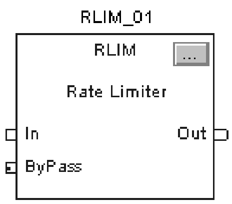
The RLIM instruction limits the amount of change of a signal over time.

Operands:

```
RLIM(RLIM_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
RLIM tag	RATE_LIMITER	structure	RLIM structure



Function Block

Operand:	Type:	Format:	Description:
RLIM tag	RATE_LIMITER	structure	RLIM structure

RATE_LIMITER Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
IncRate	REAL	Maximum output increment rate in per-second units. If invalid, the instruction sets IncRate = 0.0 and sets the appropriate bit in Status. Valid = any float ≥ 0.0 Default = 0.0
DecRate	REAL	Maximum output decrement rate in per-second units. If invalid, the instruction sets DecRate = 0.0 and sets the appropriate bit in Status. Valid = any float ≥ 0.0 Default = 0.0
ByPass	BOOL	Request to bypass the algorithm. When set, Out = In. Default is cleared.
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode For more information about timing modes, see appendix Function Block Attributes. Valid = 0 to 2 Default = 0

Input Parameter:	Data Type:	Description:
OversampleDT	REAL	Execution time for oversample mode. Valid = 0 to 4194.303 seconds Default = 0
RTSTime	DINT	Module update period for real time sampling mode Valid = 1 to 32,767ms Default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling mode. Valid = 0 to 32,767ms Default = 0

<table>
<tr><th>Output Parameter:</th><th>Data Type:</th><th>Description:</th></tr>
<tr><td>EnableOut</td><td>BOOL</td><td>Enable output.</td></tr>
<tr><td>Out</td><td>REAL</td><td>The calculated output of the algorithm. Arithmetic status flags are set for this output.</td></tr>
<tr><td>DeltaT</td><td>REAL</td><td>Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output.</td></tr>
<tr><td>Status</td><td>DINT</td><td>Status of the function block.</td></tr>
<tr><td>InstructFault (Status.0)</td><td>BOOL</td><td>The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.</td></tr>
<tr><td>IncRateInv (Status.1)</td><td>BOOL</td><td>IncRate < 0. The instruction uses 0.</td></tr>
<tr><td>DecRate (Status.2)</td><td>BOOL</td><td>DecRate < 0. The instruction uses 0.</td></tr>
<tr><td>TimingModeInv
(Status.27)</td><td>BOOL</td><td>Invalid TimingMode value.
For more information about timing modes, see appendix Function Block Attributes.</td></tr>
<tr><td>RTSMissed (Status.28)</td><td>BOOL</td><td>Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).</td></tr>
<tr><td>RTSTimeInv
(Status.29)</td><td>BOOL</td><td>Invalid RTSTime value.</td></tr>
<tr><td>RTSTimeStampInv
(Status.30)</td><td>BOOL</td><td>Invalid RTSTimeStamp value.</td></tr>
<tr><td>DeltaTInv (Status.31)</td><td>BOOL</td><td>Invalid DeltaT value.</td></tr>
</table>

Description: The RLIM instruction provides separate increment and decrement rates in per-second units. The ByPass input lets you stop rate limiting and pass the signal directly to the output.

Condition:	Action:
ByPass is set	$Out_n = In_n$ $Out_{n-1} = In_n$
ByPass is cleared **and** DeltaT > 0	$Slope = \frac{In_n - Out_{n-1}}{DeltaT}$ If Slope ≤ –DecRate then YSlope = –DecRate If –DecRate ≤ Slope ≤ IncRate then YSlope = Slope If IncRate ≤ Slope then YSlope = IncRate $Out_n = Out_{n-1}$ + DeltaT x YSlope $Out_{n-1} = Out_n$ where DeltaT is in seconds

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

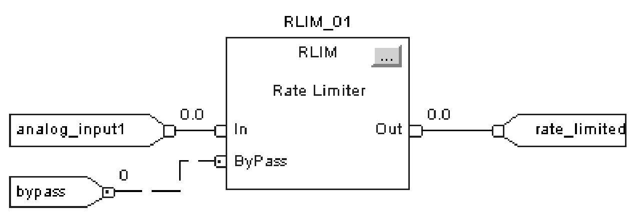
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	$Out_{n-1} = In_n$	$Out_{n-1} = In_n$
instruction first run	$Out_{n-1} = In_n$	$Out_{n-1} = In_n$
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The RLIM instruction limits In by IncRate. If analog_input1 changes at a rate greater than the IncRate value, the instruction limits In. The instruction sets Out = rate limited value of In.

Structured Text

```
RLIM_01.In := analog_input1;
RLIM_01.Bypass := bypass;
RLIM(RLIM_01);

rate_limited := RLIM_01.Out;
```

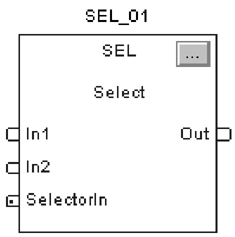
Function Block



Select (SEL)

The SEL instruction uses a digital input to select one of two inputs.

Operands:



Function Block

Operand:	Type:	Format:	Description:
SEL tag	SELECT	structure	SEL structure

SELECT Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	Enable input. If cleared, the instruction does not execute and outputs are not updated. Default is set.
In1	REAL	The first analog signal input to the instruction. Valid = any float Default = 0.0
In2	REAL	The second analog signal input to the instruction. Valid = any float Default = 0.0
SelectorIn	BOOL	The input that selects between In1 and In2. Default is cleared.
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.

Description:

The SEL instruction operates as follows:

Condition:	Action:
SelectorIn is set	Out = In2
SelectorIn is cleared	Out = In1

Arithmetic Status Flags:

Arithmetic status flags are set for the Out output.

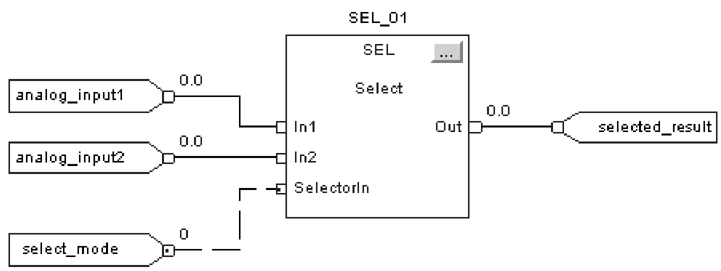
Fault Conditions:

none

Execution:

Condition:	Function Block Action:
prescan	No action taken.
instruction first scan	No action taken.
instruction first run	No action taken.
EnableIn is cleared	EnableOut is cleared.
EnableIn is set	The instruction executes. EnableOut is set.
postscan	No action taken.

Example: The SEL instruction selects In1 or In2 based on SelectorIn. If SelectorIn is set, the instruction sets Out = In2. If SelectorIn is cleared, the instruction sets Out = In1.



Selected Negate (SNEG)

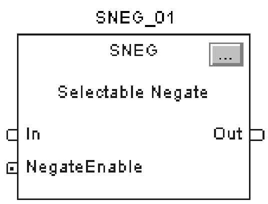
The SNEG instruction uses a digital input to select between the input value and the negative of the input value.

Operands:

```
SNEG(SNEG_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
SNEG tag	SELECTABLE_NEGATE	structure	SNEG structure



Function Block

Operand:	Type:	Format:	Description:
SNEG tag	SELECTABLE_NEGATE	structure	SNEG structure

SELECTABLE_NEGATE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction.
NegateEnable	BOOL	Negate enable. When NegateEnable is set, the instruction sets Out to the negative value of In. Default is set.
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.

Description:

The SNEG instruction operates as follows:

Condition:	Action:
NegateEnable is set	Out = –In
NegateEnable is cleared	Out = In

Arithmetic Status Flags:

Arithmetic status flags are set for the Out output.

Fault Conditions:

none

Execution:

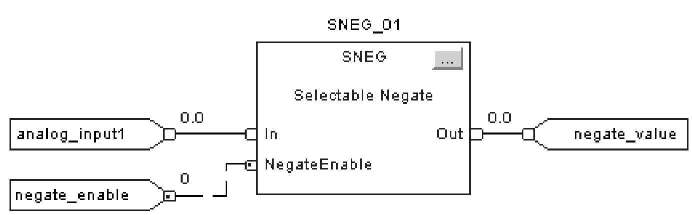
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The tag negate_enable determines whether to negate In or not. The instruction sets Out = In if NegateEnable is cleared. The instruction sets Out = -In if NegateEnable is set.

Structured Text

```
SNEG_01.In := analog_input1
SNEG_01.NegateEnable := negate_enable;
SNEG(SNEG_01);

negate_value := SNEG_01.Out;
```

Function Block



Selected Summer (SSUM)

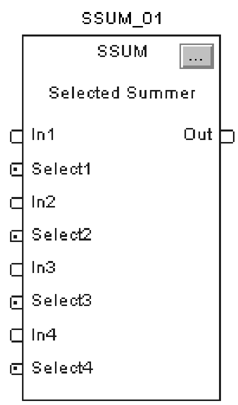
The SSUM instruction uses boolean inputs to select real inputs to be algebraically summed.

Operands:

```
SSUM(SSUM_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
SSUM tag	SELECTABLE_SUMMER	structure	SSUM structure



Function Block

Operand:	Type:	Format:	Description:
SSUM tag	SELECTABLE_SUMMER	structure	SSUM structure

SELECTABLE_SUMMER Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In1	REAL	The first input to be summed. Valid = any float Default = 0.0
Gain1	REAL	Gain for the first input. Valid = any float Default = 1.0
Select1	BOOL	Selector signal for the first input. Default is cleared.
In2	REAL	The second input to be summed. Valid = any float Default = 0.0
Gain2	REAL	Gain for the second input. Valid = any float Default = 1.0
Select2	BOOL	Selector signal for the second input. Default is cleared.

Input Parameter:	Data Type:	Description:
In3	REAL	The third input to be summed. Valid = any float Default = 0.0
Gain3	REAL	Gain for the third input. Valid = any float Default = 1.0
Select3	BOOL	Selector signal for the third input. Default is cleared.
In4	REAL	The fourth input to be summed. Valid = any float Default = 0.0
Gain4	REAL	Gain for the fourth input. Valid = any float Default = 1.0
Select4	BOOL	Selector signal for the fourth input. Default is cleared.
In5	REAL	The fifth input to be summed. Valid = any float Default = 0.0
Gain5	REAL	Gain for the fifth input. Valid = any float Default = 1.0
Select5	BOOL	Selector signal for the fifth input. Default is cleared.
In6	REAL	The sixth input to be summed. Valid = any float Default = 0.0
Gain6	REAL	Gain for the sixth input. Valid = any float Default = 1.0
Select6	BOOL	Selector signal for the sixth input. Default is cleared.
In7	REAL	The seventh input to be summed. Valid = any float Default = 0.0
Gain7	REAL	Gain for the seventh input. Valid = any float Default = 1.0
Select7	BOOL	Selector signal for the seventh input. Default is cleared.
In8	REAL	The eighth input to be summed. Valid = any float Default = 0.0

Input Parameter:	Data Type:	Description:
Gain8	REAL	Gain for the eighth input. Valid = any float Default = 1.0
Select8	BOOL	Selector signal for the eighth input. Default is cleared.
Bias	REAL	Bias signal input. The instruction adds the Bias to the sum of the inputs. Valid = any float Default = 0.0

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.

Description:

The SSUM instruction operates as follows:

Condition:	Action:
No In is selected	$Out = Bias$
In is selected	$Out = \sum_{n=1}^{8} (In_n \times Gain_n) + Bias$

Arithmetic Status Flags:

Arithmetic status flags are set for the Out output.

Fault Conditions:

none

Execution:

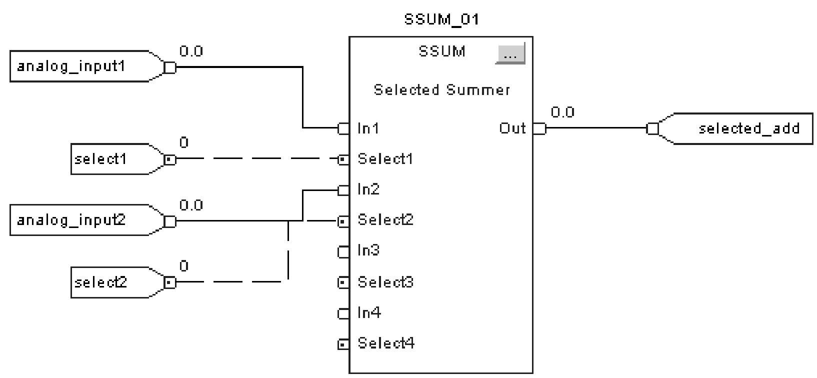
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	No action taken.	No action taken.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: The values of Select1 and Select2 determine whether to select analog_input1 and analog_input2, respectively. The instruction then adds the selected inputs and places the result in Out.

Structured Text

```
SSUM_01.In1 := analog_input1;
SSUM_01.Select1 := select1;
SSUM_01.In2 := analog_input2;
SSUM_01.Select2 := select2;
SSUM(SSUM_01);

selected_add := SSUM_01.Out;
```

Function Block



Statistical Instructions
(MAVE, MAXC, MINC, MSTD)

Introduction

These statistical instructions are available:

If you want to:	Use this instruction:	Available in these languages:	See page:
calculate a time average value.	Moving Average (MAVE)	structured text function block	5-2
find the maximum signal in time.	Maximum Capture (MAXC)	structured text function block	5-6
find the minimum signal in time.	Minimum Capture (MINC)	structured text function block	5-8
calculate a moving standard deviation.	Moving Standard Deviation (MSTD)	structured text function block	5-10

Moving Average (MAVE)

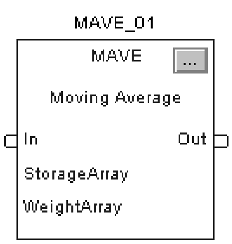
The MAVE instruction calculates a time average value for the In signal. This instruction optionally supports user-specified weights.

Operands:

```
MAVE(MAVE_tag,storage,weight);
```

Structured Text

Operand:	Type:	Format:	Description:
MAVE tag	MOVING_AVERAGE	structure	MAVE structure
storage	REAL	array	holds the moving average samples. This array must be at least as large as NumberOfSamples.
weight	REAL	array	(optional) used for weighted averages. This array must be at least as large as NumberOfSamples. Element [0] is used for the newest sample; element [n] is used for the oldest sample.



Function Block

The operands are the same as for the structured text FGEN instruction.

MOVING_AVERAGE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
InFault	BOOL	Bad health indicator for the input. If In is read from an analog input, then InFault is normally controlled by fault status on the analog input. When set, InFault indicates that the input signal has an error, the instruction sets the appropriate bit in Status, and the instruction holds Out at its current value. When InFault transitions from set to cleared, the instruction initializes the averaging algorithm and continues executing. Default is cleared.

Input Parameter:	Data Type:	Description:
Initialize	BOOL	Initialize input to the instruction. When set, the instruction holds Out = In, except when InFault is set, in which case, the instruction holds Out at its current value. When Initialize transitions from set to cleared, the instruction initializes the averaging algorithm and continues executing. Default is cleared.
SampleEnable	BOOL	Enable for taking a sample of In. When set, the instruction enters the value of In into the storage array and calculates a new Out value. When SampleEnable is cleared and Initialize is cleared, the instruction holds Out at its current value. Default is set.
NumberOfSamples	DINT	The number of samples to be used in the calculation. If this value is invalid, the instruction sets the appropriate bit in Status and holds Out at its current value. When NumberOfSamples becomes valid again, the instruction initializes the averaging algorithm and continues executing. Valid = 1 to (minimum size of StorageArray or WeightArray (if used)) Default = 1
UseWeights	BOOL	Averaging scheme input to the instruction. When set, the instruction uses the weighted method to calculate the Out. When cleared, the instruction uses the uniform method to calculate Out. Default is cleared.

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
InFaulted (Status.1)	BOOL	In health is bad (InFault is set).
NumberOfSampInv (Status.2)	BOOL	NumberOfSamples invalid or not compatible with array size.

Description:

The MAVE instruction calculates a weighted or non-weighted moving average of the input signal. The NumberOfSamples specifies the length of the moving average span. At every scan of the block when SampleEnable is set, the instruction moves the value of In into the storage array and discards the oldest value. Each In_n has a user configured $Weight_n$, which is used if UseWeights is set.

The MAVE instructions uses these equations:

Condition:	Equation:
weighted averaging method UseWeights is set	$Out = \sum_{n=1}^{NumberOfSamples} Weight_n \times In_n$
uniform averaging method UseWeights is cleared	$Out = \dfrac{\sum_{n=1}^{NumberOfSamples} In_n}{NumberOfSamples}$

The instruction will not place an invalid In value (NAN or ±INF) into the storage array. When In is invalid, the instruction sets Out = In and sets the arithmetic overflow status flag. When In becomes valid, the instruction initializes the averaging algorithm and continues executing.

You can make runtime changes to the NumberOfSamples parameter. If you increase the number, the instruction incrementally averages new data from the current sample size to the new sample size. If you decrease the number, the instruction re-calculates the average from the beginning of the sample array to the new NumberOfSamples value.

Initializing the averaging algorithm

Certain conditions, such as instruction first scan and instruction first run, require the instruction to initialize the moving average algorithm. When this occurs, the instruction considers the sample array empty and incrementally averages samples from 1 to the NumberOfSamples value. For example:

NumberOfSamples = 3, UseWeights is set
- Scan 1: Out = In_n*$Weight_1$
- Scan 2: Out = (In_n*$Weight_1$)+(In_{n-1}*$Weight_2$)
- Scan 3: Out = (In_n*$Weight_1$)+(In_{n-1}*$Weight_2$) +(In_{n-2}*$Weight_3$)

NumberOfSamples = 3, UseWeights is cleared
- Scan 1: Out = In_n/1
- Scan 2: Out = (In_n+In_{n-1})/2
- Scan 3: Out = (In_n+In_{n-1}+In_{n-2})/NumberOfSamples

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

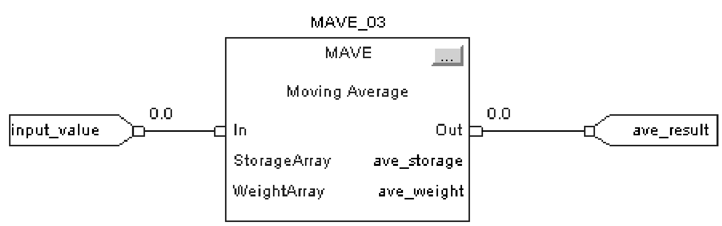
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	If InFault is cleared, the instruction initializes the algorithm and continues.	If InFault is cleared, the instruction initializes the algorithm and continues.
instruction first run	If InFault is cleared, the instruction initializes the algorithm and continues.	If InFault is cleared, the instruction initializes the algorithm and continues.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: Each scan, the instruction places input_value in array storage. The instruction calculates the average of the values in array storage, optionally using the weight values in array weight, and places the result in Out.

Structured Text

```
MAVE_03.In := input_value;
MAVE(MAVE_03,ave_storage,ave_weight);
ave_result := MAVE_03.Out;
```

Function Block



Maximum Capture (MAXC)

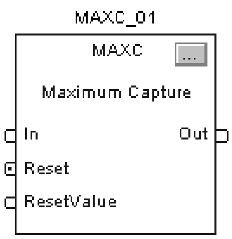
The MAXC instruction finds the maximum of the Input signal over time.

Operands:

```
MAXC(MAXC_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
MAXC tag	MAXIMUM_CAPTURE	structure	MAXC structure



Function Block

Operand:	Type:	Format:	Description:
MAXC tag	MAXIMUM_CAPTURE	structure	MAXC structure

MAXIMUM_CAPTURE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Reset	BOOL	Request to reset control algorithm. The instruction sets Out = ResetValue as long as Reset is set. Default is cleared.
ResetValue	REAL	The reset value for instruction. The instruction sets Out = ResetValue as long as Reset is set. Valid = any float Default = 0.0
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.

Description:

The MAXC instruction executes this algorithm:

Condition:	Action:
Reset is set	Out_{n-1} = ResetValue Out = ResetValue
Reset is cleared	Out = In when In > Out_{n-1} Out = Out_{n-1} when In ≤ Out_{n-1} Out_{n-1} = Out

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

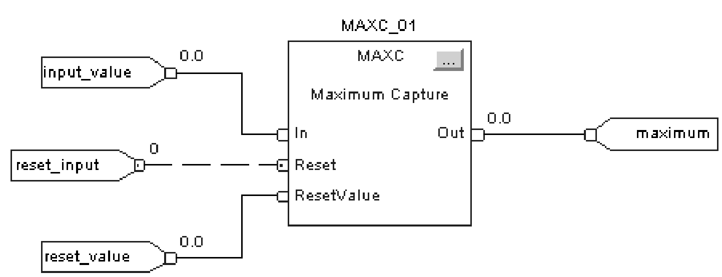
Condition:	Action:	Action:
prescan	No action taken.	No action taken.
instruction first scan	Out_{n-1} = In	Out_{n-1} = In
instruction first run	Out_{n-1} = In	Out_{n-1} = In
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: If Reset is set, the instruction sets Out = ResetValue. If Reset is cleared, the instruction sets Out = In when In > Out_{n-1}. Otherwise, the instruction sets Out = Out_{n-1}.

Structured Text

```
MAXC_01.In := input_value;
MAXC_01.Reset := reset_input;
MAXC_01.ResetValue := reset_value;
MAXC(MAXC_01);
maximum := MAXC_01.Out;
```

Function Block



Minimum Capture (MINC)

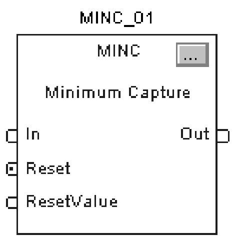
The MINC instruction finds the minimum of the Input signal over time.

Operands:

```
MINC(MINC_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
MINC tag	MINIMUM_CAPTURE	structure	MINC structure



Function Block

Operand:	Type:	Format:	Description:
MINC tag	MINIMUM_CAPTURE	structure	MINC structure

MINIMUM_CAPTURE Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
Reset	BOOL	Request to reset control algorithm. The instruction sets Out = ResetValue as long as Reset is set. Default is cleared.
ResetValue	REAL	The reset value for instruction. The instruction sets Out = ResetValue as long as Reset is set. Valid = any float Default = 0.0
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. Arithmetic status flags are set for this output.

Description:

The MINC instruction executes this algorithm:

Condition:	Action:
Reset is set	Out_{n-1} = ResetValue Out = ResetValue
Reset is cleared	Out = In when In < Out_{n-1} Out = Out_{n-1} when In $\geq$ Out_{n-1} Out_{n-1} = Out

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

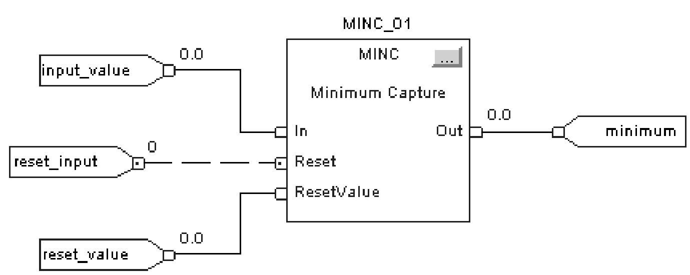
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	Out_{n-1} = In	Out_{n-1} = In
instruction first run	Out_{n-1} = In	Out_{n-1} = In
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: If Reset is set, the instruction sets Out = ResetValue. If Reset is cleared, the instruction sets Out = In when In < Out_{n-1}. Otherwise, the instruction sets Out = Out_{n-1}.

Structured Text

```
MINC_01.In := input_value;
MINC_01.Reset := reset_input;
MINC_01.ResetValue := reset_value;
MINC(MINC_01);
minimum := MINC_01.Out;
```

Function Block



Moving Standard Deviation (MSTD)

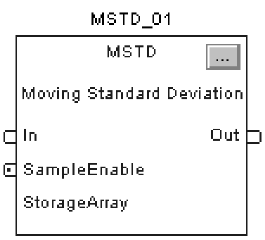
The MSTD instruction calculates a moving standard deviation and average for the In signal.

Operands:

```
MSTD(MSTD_tag,storage);
```

Structured Text

Operand:	Type:	Format:	Description:
MSTD tag	MOVING_STD_DEV	structure	MSTD structure
storage	REAL	array	holds the In samples. This array must be at least as large as NumberOfSamples.



Function Block

Operand:	Type:	Format:	Description:
MSTD tag	MOVING_STD_DEV	structure	MSTD structure
storage	REAL	array	holds the In samples. This array must be at least as large as NumberOfSamples.

MOVING_STD_DEV Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
In	REAL	The analog signal input to the instruction. Valid = any float Default = 0.0
InFault	BOOL	Bad health indicator for the input. If In is read from an analog input, then InFault is normally controlled by fault status on the analog input. When set, InFault indicates that the input signal has an error, the instruction sets the appropriate bit in Status, and the instruction holds Out and Average at their current values. When InFault transitions from set to cleared, the instruction initializes the averaging algorithm and continues executing. Default is cleared.

Input Parameter:	Data Type:	Description:
Initialize	BOOL	Initialize input to the instruction. When set, the instruction sets Out = 0.0 and Average = In, except when InFault is set, in which case, the instruction holds both Out and Average at their current values. When Initialize transitions from set to cleared, the instruction initializes the standard deviation algorithm and continues executing. Default is cleared.
SampleEnable	BOOL	Enable for taking a sample of In. When set, the instruction enters the value of In into the storage array and calculates a new Out and Average value. When SampleEnable is cleared and Initialize is cleared, the instruction holds Out and Average at their current values. Default is cleared.
NumberOfSamples	DINT	The number of samples to be used in the calculation. If this value is invalid, the instruction sets the appropriate bit in Status and the instruction holds Out and Average at their current values. When NumberOfSamples becomes valid again, the instruction initializes the standard deviation algorithm and continues executing. Valid = 1 to size of the storage array Default = 1

Output Parameter:	Data Type:	Description:
EnableOut	BOOL	Enable output.
Out	REAL	The calculated output of the algorithm. The instruction holds Out at its current value when SampleEnable is cleared. Arithmetic status flags are set for this output.
Average	REAL	The calculated average of the algorithm.
Status	DINT	Status of the function block.
InstructFault (Status.0)	BOOL	The instruction detected one of the following execution errors. This is not a minor or major controller error. Check the remaining status bits to determine what occurred.
InFaulted (Status.1)	BOOL	In health is bad. InFault is set.
NumberOfSamplInv (Status.2)	BOOL	NumberOfSamples invalid or not compatible with array size.

Description:

The MSTD instruction supports any input queue length. Each scan, if SampleEnable is set, the instruction enters the value of In into a storage array. When the storage array is full, each new value of In causes the oldest entry to be deleted.

The MSTD instructions uses these equations for the outputs:

Condition:	Equals:
Average	$Average = \frac{\sum_{n=1}^{NumberOfSamples} In_n}{NumberOfSamples}$
Out	$Out = \sqrt{\frac{\sum_{n=1}^{NumberOfSamples} (In_n - Average)^2}{NumberOfSamples}}$

The instruction will not place an invalid In value (NAN or ±INF) into the storage array. When In is invalid, the instruction sets Out = In, sets Average = In, and sets the arithmetic overflow status flag. When In becomes valid, the instruction initializes the standard deviation algorithm and continues executing.

You can make runtime changes to the NumberOfSamples parameter. If you increase the number, the instruction incrementally processes new data from the current sample size to the new sample size. If you decrease the number, the instruction re-calculates the standard deviation from the beginning of the sample array to the new NumberOfSamples value.

Initializing the standard deviation algorithm

Certain conditions, such as instruction first scan and instruction first run, require the instruction to initialize the standard deviation algorithm. When this occurs, the instruction considers the sample array empty and incrementally processes samples from 1 to the NumberOfSamples value. For example:

NumberOfSamples = 3

Scan 1: Average = $In_n/1$

Out = Square root $(((In_n\text{-Average})^2)/1)$

Scan 2: Average = $(In_n+In_{n-1})/2$

Out = Square root $(((In_n\text{-Average})^2+(In_{n-1}\text{-Average})^2)/2)$

Scan 3: Average = $(In_n+In_{n-1}+In_{n-2})/\text{NumberOfSamples}$

Out = Square root $(((In_n\text{-Average})^2+(In_{n-1}\text{-Average})^2+(In_{n-2}\text{-Average})^2)/\text{NumberOfSamples})$

Arithmetic Status Flags: Arithmetic status flags are set for the Out output.

Fault Conditions: none

Execution:

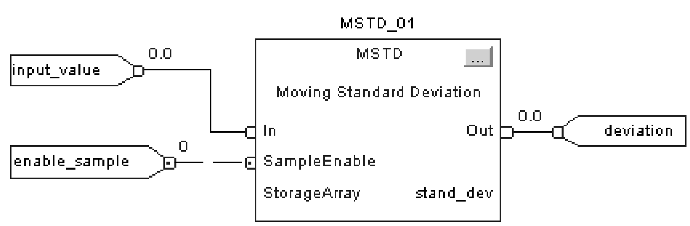
Condition:	Function Block Action:	Structured Test Action:
prescan	No action taken.	No action taken.
instruction first scan	If InFault is cleared, the instruction initializes the algorithm and continues.	If InFault is cleared, the instruction initializes the algorithm and continues.
instruction first run	If InFault is cleared, the instruction initializes the algorithm and continues.	If InFault is cleared, the instruction initializes the algorithm and continues.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: Each scan that SampleEnable is set, the instruction places the value of In into array storage, calculates the standard deviation of the values in array storage, and places the result in Out.

Structured Text

```
MSTD_01.In := input_value;
MSTD_01.Sample_enable := enable_sample;
MSTD(MSTD_01,stand_dev);
deviation := MSTD_01.Out;
```

Function Block



Notes:

Move/Logical Instructions
(DFF, JKFF, RESD, SETD)

Introduction

These move/logical instructions are available:

If you want to:	Use this instruction:	Available in these languages:	See page:
set the Q output to the state of the D input on a transition of the Clock input.	D Flip-Flop (DFF)	structured text function block	6-2
complement the Q and QNot outputs when the Clock input transitions.	JK Flip-Flop (JKFF)	structured text function block	6-4
use Set and Reset inputs to control latched outputs when the Reset input has precedence over the Set input.	Reset Dominant (RESD)	structured text function block	6-6
use Set and Reset inputs to control latched outputs when the Set input has precedence over the Reset input.	Set Dominant (SETD)	structured text function block	6-8

D Flip-Flop (DFF)

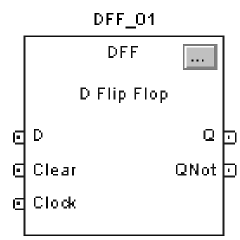
The DFF instruction sets the Q output to the state of the D input on a cleared to set transition of the Clock input. The QNot output is set to the opposite state of the Q output.

Operands:

```
DFF(DFF_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
DFF tag	FLIP_FLOP_D	structure	DFF structure



Function Block

Operand:	Type:	Format:	Description:
DFF tag	FLIP_FLOP_D	structure	DFF structure

FLIP_FLOP_D Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
D	BOOL	The input to the instruction. Default is cleared.
Clear	BOOL	Clear input to the instruction. If set, the instruction clears Q and sets QNot. Default is cleared.
Clock	BOOL	Clock input to the instruction. Default is cleared.
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Q	BOOL	The output of the instruction.
QNot	BOOL	The complement of the Q output.

Description:

When Clear is set, the instruction clears Q and sets QNot. Otherwise, if Clock is set and $Clock_{n-1}$ is cleared, the instruction sets Q = D and sets QNot = NOT (D).

The instruction sets $Clock_{n-1}$ = Clock state every scan.

Arithmetic Status Flags:

not affected

Fault Conditions: none

Execution:

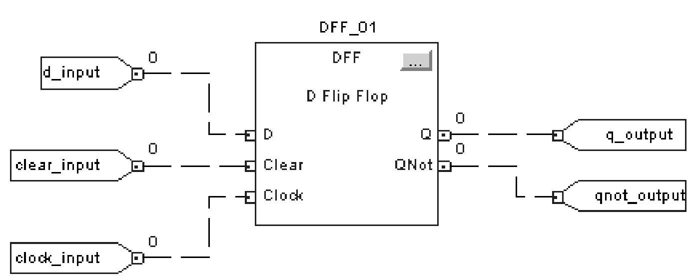
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	$Clock_{n-1}$ is set Q is cleared QNot is set	$Clock_{n-1}$ is set Q is cleared QNot is set
instruction first run	$Clock_{n-1}$ is set Q is cleared QNot is set	$Clock_{n-1}$ is set Q is cleared QNot is set
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: When Clock goes from cleared to set, the DFF instruction sets Q = D. When Clear is set, Q is cleared. The DFF instruction sets QNot to the opposite state of Q.

Structured Text

```
DFF_01.D := d_input;
DFF_01.Clear := clear_input;
DFF_01.Clock := clock_input;
DFF(DFF_01);
q_output := DFF_01.Q;
qnot_output := DFF_01.QNot;
```

Function Block



JK Flip-Flop (JKFF)

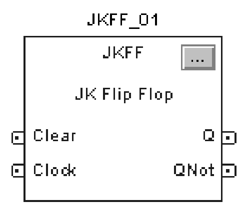
The JKFF instruction complements the Q and QNot outputs when the Clock input transitions from cleared to set.

Operands:

```
JKFF(JKFF_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
JKFF tag	FLIP_FLOP_JK	structure	JKFF structure



Function Block

Operand:	Type:	Format:	Description:
JKFF tag	FLIP_FLOP_JK	structure	JKFF structure

FLIP_FLOP_JK Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
Clear	BOOL	Clear input to the instruction. If set, the instruction clears Q and sets QNot. Default is cleared.
Clock	BOOL	Clock input to the instruction. Default is cleared.
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Q	BOOL	The output of the instruction.
QNot	BOOL	The complement of the Q output.

Description:

When Clear is set, the instruction clears Q and sets QNot. Otherwise, if Clock is set and $Clock_{n-1}$ is cleared, the instruction toggles Q and QNot.

The instruction sets $Clock_{n-1}$ = Clock state every scan.

Arithmetic Status Flags:

not affected

Fault Conditions:

none

Execution:

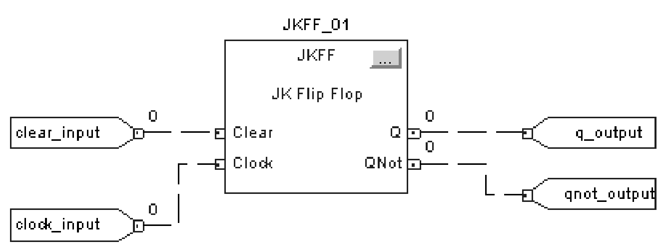
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	$Clock_{n-1}$ is set Q is cleared QNot is set	$Clock_{n-1}$ is set Q is cleared QNot is set
instruction first run	$Clock_{n-1}$ is set Q is cleared QNot is set	$Clock_{n-1}$ is set Q is cleared QNot is set
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: When Clock goes from cleared to set, the JKFF instruction toggles Q. If Clear is set, Q is always cleared. The JKFF instruction sets QNot to the opposite state of Q.

Structured Text

```
JKFF_01.Clear := clear_input;
JKFF_01.Clock := clock_input;
JKFF(JKFF_01);
q_output := JKFF_01.Q;
qnot_output := JKFF_01.QNot;
```

Function Block



Reset Dominant (RESD)

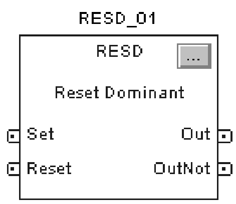
The RESD instruction uses Set and Reset inputs to control latched outputs. The Reset input has precedence over the Set input.

Operands:

```
RESD(RESD_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
RESD tag	DOMINANT_RESET	structure	RESD structure



Function Block

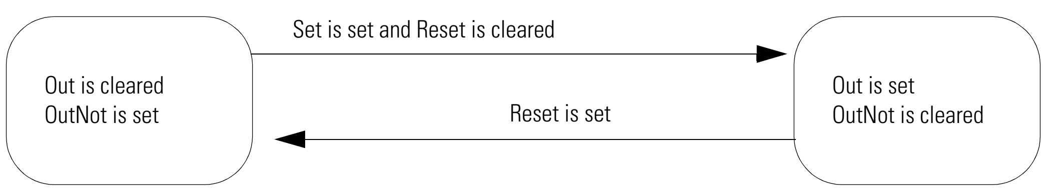
Operand:	Type:	Format:	Description:
RESD tag	DOMINANT_RESET	structure	RESD structure

DOMINANT_RESET Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
Set	BOOL	Set input to the instruction. Default is cleared.
Reset	BOOL	Reset input to the instruction. Default is cleared.
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Out	BOOL	The output of the instruction.
OutNot	BOOL	The inverted output of the instruction.

Description:

The following diagram illustrates how the RESD instruction operates



Arithmetic Status Flags:

not affected

Fault Conditions:

none

Execution:

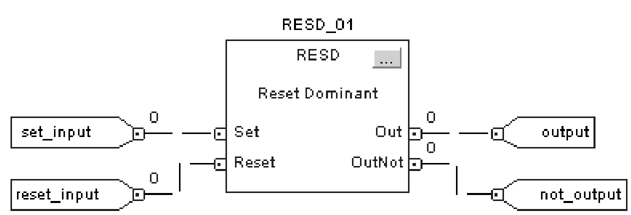
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	Out is cleared. OutNot is set.	Out is cleared. OutNot is set.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: When Set is set, Out is set; when Reset is set, Out is cleared. Reset has precedence over Set.

Structured Text

```
RESD_01.Set := set_input;
RESD_01.Reset := reset_input;
RESD(RESD_01);
output := RESD_01.Out;
not_output := RESD_01.OutNot;
```

Function Block



Set Dominant (SETD)

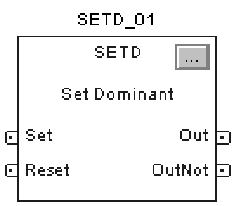
The SETD instruction uses Set and Reset inputs to control latched outputs. The Set input has precedence over the Reset input.

Operands:

```
SETD(SETD_tag);
```

Structured Text

Operand:	Type:	Format:	Description:
SETD tag	DOMINANT_SET	structure	SETD structure



Function Block

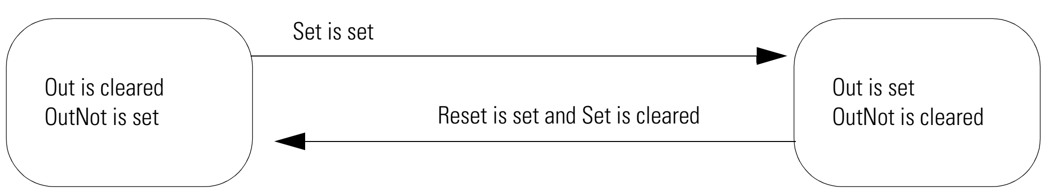
Operand:	Type:	Format:	Description:
SETD tag	DOMINANT_SET	structure	SETD structure

DOMINANT_SET Structure

Input Parameter:	Data Type:	Description:
EnableIn	BOOL	**Function Block:** If cleared, the instruction does not execute and outputs are not updated. If set, the instruction executes. Default is set. **Structured Text:** No effect. The instruction executes.
Set	BOOL	Set input to the instruction. Default is cleared.
Reset	BOOL	Reset input to the instruction. Default is cleared.
Output Parameter:	**Data Type:**	**Description:**
EnableOut	BOOL	Enable output.
Out	BOOL	The output of the instruction.
OutNot	BOOL	The inverted output of the instruction.

Description:

The following diagram illustrates how the SETD instruction operates



Arithmetic Status Flags:

not affected

Fault Conditions:

none

Execution:

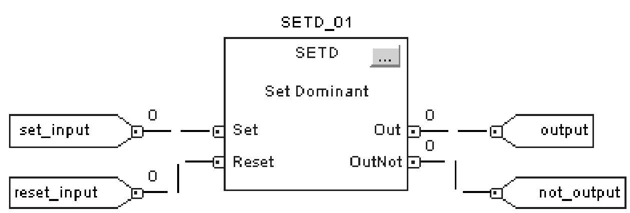
Condition:	Function Block Action:	Structured Text Action:
prescan	No action taken.	No action taken.
instruction first scan	No action taken.	No action taken.
instruction first run	Out is set. OutNot is cleared.	Out is set. OutNot is cleared.
EnableIn is cleared	EnableOut is cleared, the instruction does nothing, and the outputs are not updated.	na
EnableIn is set	The instruction executes. EnableOut is set.	EnableIn is always set. The instruction executes.
postscan	No action taken.	No action taken.

Example: When Set is set, Out is set; when Reset is set, Out is cleared. Set has precedence over Reset.

Structured Text

```
SETD_01.Set := set_input;
SETD_01.Reset := reset_input;
SETD(SETD_01);
output := SETD_01.Out;
not_output := SETD_01.OutNot;
```

Function Block



Notes:

Common Attributes

Introduction

This appendix describes attributes that are common to the Logix instructions.

Immediate Values

Whenever you enter an immediate value (constant) in decimal format (e.g., -2, 3) the controller stores the value using 32 bits. If you enter a value in a radix other than decimal, such as binary or hexadecimal, and do not specify all 32 bits, the controller places a zero in the bits that you do not specify (zero-fill).

EXAMPLE Zero-filling of immediate values

If you enter:	The controller stores:
-1	16#ffff ffff (-1)
16#ffff (-1)	16#0000 ffff (65535)
8#1234 (668)	16#0000 029c (668)
2#1010 (10)	16#0000 000a (10)

Data Conversions

Data conversions occur when you mix data types in your programming:

When programming in:	Conversions can occur when:
relay ladder logic	mix data types for the parameters within one instruction
function block	you wire two parameters that have different data types

Instructions execute faster and require less memory if all the operands of the instruction use:

- the same data type
- an optimal data type:
  - In the “Operands” section of each instruction in this manual, a bold data type indicates an optimal data type.
  - The DINT and REAL data types are typically the optimal data types.
  - Most function block instruction only support one data type (the optimal data type) for its operands.

If you mix data types and use tags that are not the optimal data type, the controller converts the data according to these rules

- Are any of the operands a REAL value?

If:	Then input operands (e.g., source, tag in an expression, limit) convert to:
Yes	REALs
No	DINTs

- After instruction execution, the result (a DINT or REAL value) converts to the destination data type, if necessary.

You cannot specify a BOOL tag in an instruction that operates on integer or REAL data types.

Because the conversion of data takes additional time and memory, you can increase the efficiency of your programs by:

- using the same data type throughout the instruction
- minimizing the use of the SINT or INT data types

In other words, use all DINT tags or all REAL tags, along with immediate values, in your instructions.

The following sections explain how the data is converted when you use SINT or INT tags or when you mix data types.

SINT or INT to DINT

For those instructions that convert SINT or INT values to DINT values, the "Operands" sections in this manual identify the conversion method.

This conversion method:	Converts data by placing:
Sign-extension	the value of the left-most bit (the sign of the value) into each bit position to the left of the existing bits until there are 32 bits.
Zero-fill	zeroes to the left of the existing bits until there are 32 bits

The following example shows the results of converting a value using sign-extension and zero-fill.

This value	2#1111_1111_1111_1111	(-1)
Converts to this value by sign-extension	2#1111_1111_1111_1111_1111_1111_1111_1111	(-1)
Converts to this value by zero-fill	2#0000_0000_0000_0000_1111_1111_1111_1111	(65535)

Because immediate values are always zero-filled, the conversion of a SINT or INT value may produce unexpected results. In the following example, the comparison is false because Source A, an INT, converts by sign-extension; while Source B, an immediate value, is zero-filled.

If you use a SINT or INT tag and an immediate value in an instruction that converts data by sign-extension, use one of these methods to handle immediate values:

- Specify any immediate value in the decimal radix
- If you are entering the value in a radix other than decimal, specify all 32 bits of the immediate value. To do so, enter the value of the left-most bit into each bit position to its left until there are 32 bits.
- Create a tag for each operand and use the same data type throughout the instruction. To assign a constant value, either:
  – Enter it into one of the tags
  – Add a MOV instruction that moves the value into one of the tags.
- Use a MEQ instruction to check only the required bits

The following examples show two ways to mix an immediate value with an INT tag. Both examples check the bits of a 1771 I/O module to determine if all the bits are on. Since the input data word of a 1771 I/O module is an INT tag, it is easiest to use a 16-bit constant value.

EXAMPLE

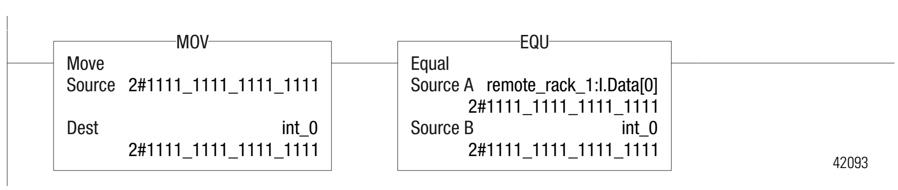
Mixing an INT tag with an immediate value

Since remote_rack_1:I.Data[0] is an INT tag, the value to check it against is also entered as an INT tag.

EXAMPLE

Mixing an INT tag with an immediate value

Since remote_rack_1:I.Data[0] is an INT tag, the value to check it against first moves into int_0, also an INT tag. The EQU instruction then compares both tags.



Integer to REAL

The controller stores REAL values in IEEE single-precision, floating-point number format. It uses one bit for the sign of the value, 23 bits for the base value, and eight bits for the exponent (32 bits total). If you mix an integer tag (SINT, INT, or DINT) and a REAL tag as inputs in the same instruction, the controller converts the integer value to a REAL value before the instruction executes.

- A SINT or INT value always converts to the same REAL value.
- A DINT value may not convert to the same REAL value:
  - A REAL value uses up to 24 bits for the base value (23 stored bits plus a "hidden" bit).
  - A DINT value uses up to 32 bits for the value (one for the sign and 31 for the value).
  - If the DINT value requires more than 24 significant bits, it may not convert to the same REAL value. If it will not, the controller rounds to the nearest REAL value using 24 significant bits.

DINT to SINT or INT

To convert a DINT value to a SINT or INT value, the controller truncates the upper portion of the DINT and sets the overflow status flag, if necessary. The following example shows the result of a DINT to SINT or INT conversion.

EXAMPLE Conversion of a DINT to an INT and a SINT

This DINT value:	Converts to this smaller value:	
16#0001_0081 (65,665)	INT:	16#0081 (129)
	SINT:	16#81 (-127)

REAL to an integer

To convert a REAL value to an integer value, the controller rounds the fractional part and truncates the upper portion of the non-fractional part. If data is lost, the controller sets the overflow status flag. Numbers round as follows:

- Numbers other than x.5 round to the nearest whole number.
- X.5 rounds to the nearest even number.

The following example show the result of converting REAL values to DINT values.

EXAMPLE Conversion of REAL values to DINT values

This REAL value:	Converts to this DINT value:
-2.5	-2
-1.6	-2
-1.5	-2
-1.4	-1
1.4	1
1.5	2
1.6	2
2.5	2

IMPORTANT The arithmetic status flags are set based on the value being stored. Instructions that normally do not affect arithmetic status keywords might appear to do so if type conversion occurs because of mixed data types for the instruction parameters. The type conversion process sets the arithmetic status keywords.

Function Block Attributes

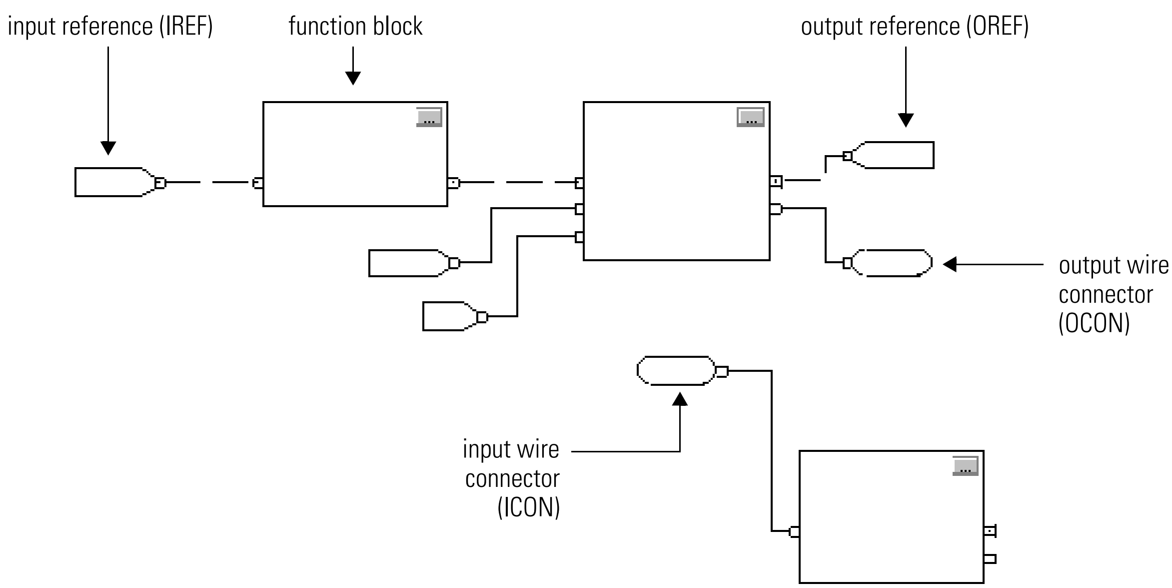
Introduction

This appendix describes issues that are unique with function block instructions. Review the information in this appendix to make sure you understand how your function block routines will operate.

IMPORTANT When programming in function block, restrict the range of engineering units to $+/-10^{+/-15}$ because internal floating point calculations are done using single precision floating point. Engineering units outside of this range may result in a loss of accuracy if results approach the limitations of single precision floating point ($+/-10^{+/-38}$).

Choose the Function Block Elements

To control a device, use the following elements:

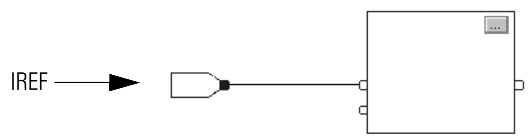


Use the following table to choose your function block elements:

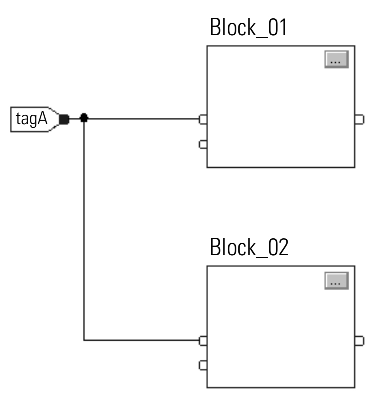
If you want to:	Then use a:
supply a value from an input device or tag	input reference (IREF)
send a value to an output device or tag	output reference (OREF)
perform an operation on an input value or values and produce an output value or values	function block
transfer data between function blocks when they are: • far apart on the same sheet • on different sheets within the same routine	output wire connector (OCON) and an input wire connector (ICON)
disperse data to several points in the routine	single output wire connector (OCON) and multiple input wire connectors (ICON)

Latching Data

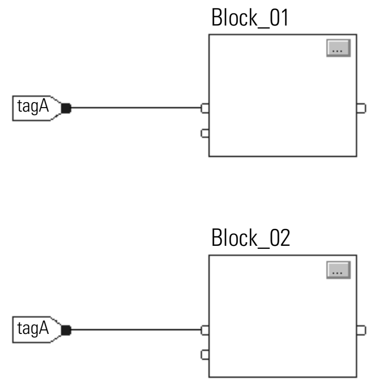
If you use an IREF to specify input data for a function block instruction, the data in that IREF is latched for the scan of the function block routine. The IREF latches data from program-scoped and controller-scoped tags. The controller updates all IREF data at the beginning of each scan.



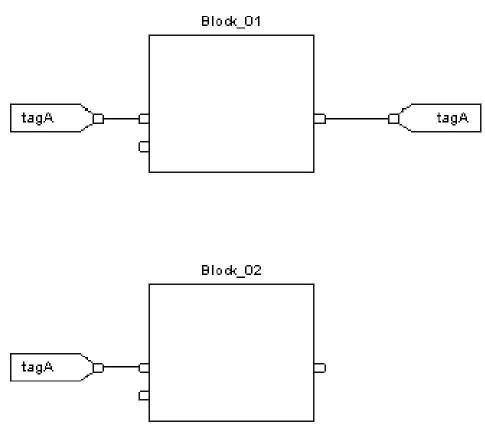
In this example, the value of tagA is stored at the beginning of the routine's execution. The stored value is used when Block_01 executes. The same stored value is also used when Blcock_02 executes. If the value of tagA changes during execution of the routine, the stored value of tagA in the IREF does not change until the next execution of the routine.



This example is the same as the one above. The value of tagA is stored only once at the beginning of the routine's execution. The routine uses this stored value throughout the routine.



Starting with RSLogix 5000 software, version 11, you can use the same tag in multiple IREFs and an OREF in the same routine. Because the values of tags in IREFs are latched every scan through the routine, all IREFs will use the same value, even if an OREF obtains a different tag value during execution of the routine. In this example, if tagA has a value of 25.4 when the routine starts executing this scan, and Block_01 changes the value of tagA to 50.9, the second IREF wired into Block_02 will still use a value of 25.4 when Block_02 executes this scan. The new tagA value of 50.9 will not be used by any IREFs in this routine until the start of the next scan.



Order of Execution

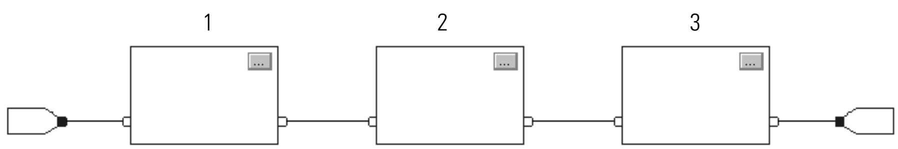
The RSLogix 5000 programming software automatically determines the order of execution for the function blocks in a routine when you:

- verify a function block routine
- verify a project that contains a function block routine
- download a project that contains a function block routine

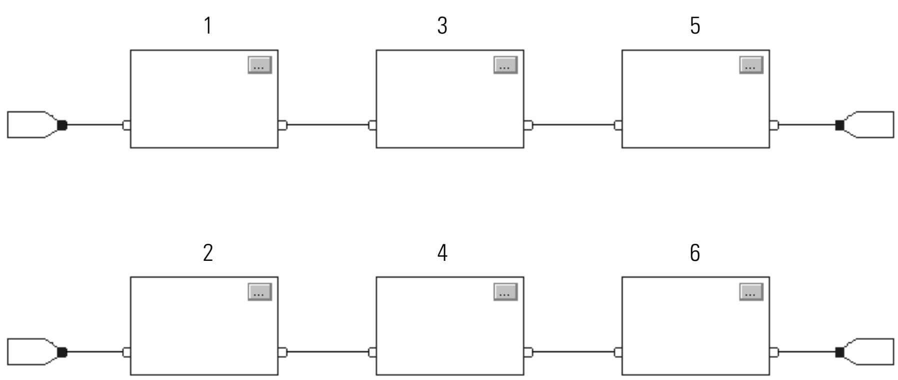
You define execution order by wiring function blocks together and indicating the data flow of any feedback wires, if necessary.

If function blocks are not wired together, it does not matter which block executes first. There is no data flow between the blocks.

If you wire the blocks sequentially, the execution order moves from input to output. The inputs of a block require data to be available before the controller can execute that block. For example, block 2 has to execute before block 3 because the outputs of block 2 feed the inputs of block 3.

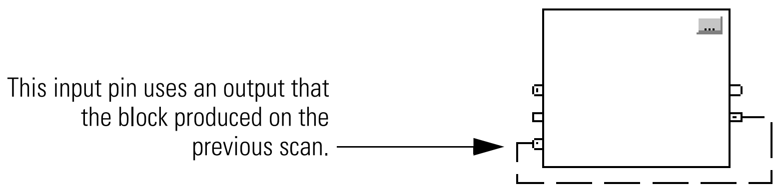


Execution order is only relative to the blocks that are wired together. The following example is fine because the two groups of blocks are not wired together. The blocks within a specific group execute in the appropriate order in relation to the blocks in that group.

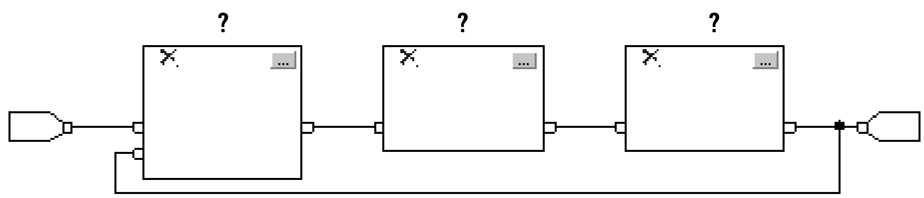


Resolve a Loop

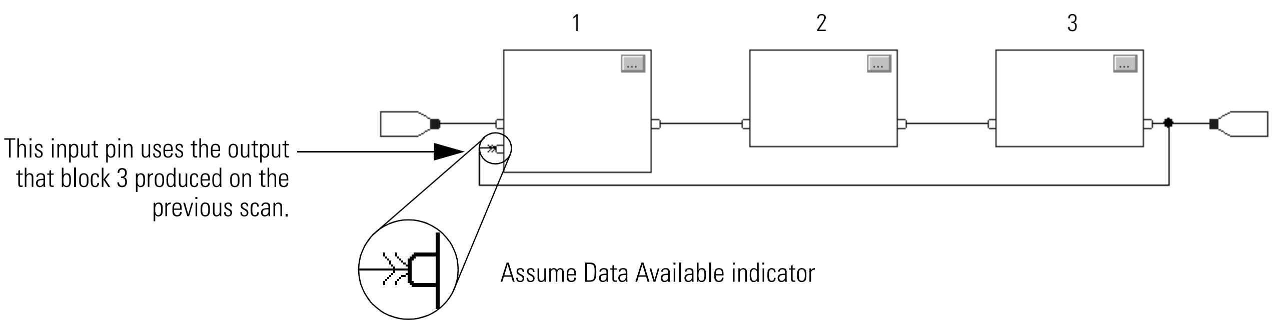
To create a feedback loop around a block, wire an output pin of the block to an input pin of the same block. The following example is OK. The loop contains only a single block, so execution order does not matter



If a group of blocks are in a loop, the controller cannot determine which block to execute first. In other words, it cannot resolve the loop.

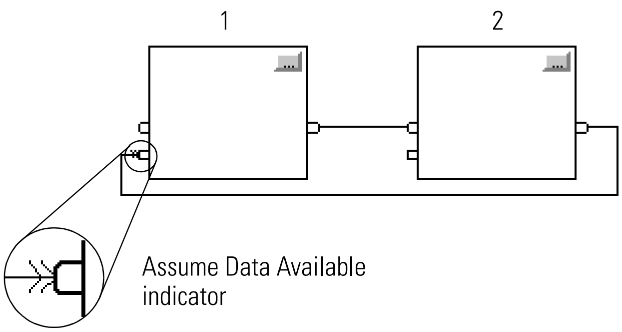
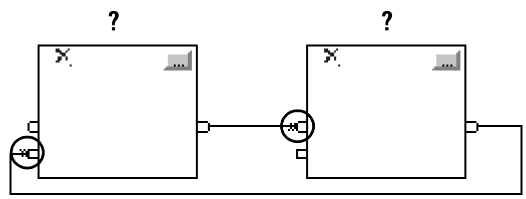


To identify which block to execute first, mark the input wire that creates the loop (the feedback wire) with the Assume Data Available indicator. In the following example, block 1 uses the output from block 3 that was produced in the previous execution of the routine.



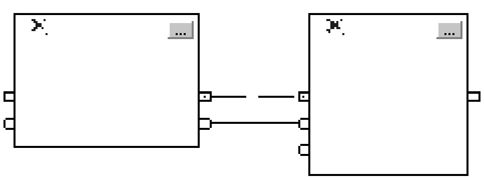
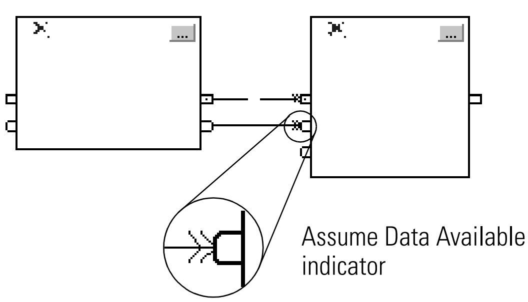
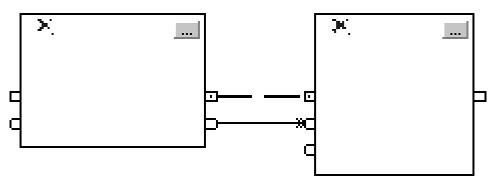
The Assume Data Available indicator defines the data flow within the loop. The arrow indicates that the data serves as input to the first block in the loop.

Do not mark all the wires of a loop with the Assume Data Available indicator.

This is OK	This is NOT OK
 The *Assume Data Available* indicator defines the data flow within the loop.	 The controller cannot resolve the loop because all the wires use the *Assume Data Available* indicator.

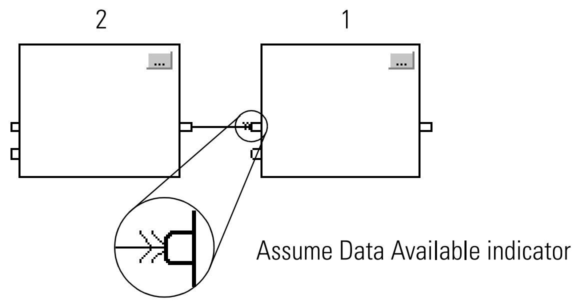
Resolve Data Flow Between Two Blocks

If you use two or more wires to connect two blocks, use the same data flow indicators for all of the wires between the two blocks.

This is OK	This is NOT OK
 Neither wire uses the *Assume Data Available* indicator.  Both wires use the *Assume Data Available* indicator.	 One wire uses the *Assume Data Available* indicator while the other wire does not.

Create a One Scan Delay

To produce a one scan delay between blocks, use the Assume Data Available indicator. In the following example, block 1 executes first. It uses the output from block 2 that was produced in the previous scan of the routine.



Summary

In summary, a function block routine executes in this order:

1. The controller latches all data values in IREFs.

2. The controller executes the other function blocks in the order determined by how they are wired.

3. The controller writes outputs in OREFs.

Function Block Responses to Overflow Conditions

In general, the function block instructions that maintain history do not update history with ±NAN, or ±INF values when an overflow occurs. Each instruction has one of these responses to an overflow condition:

Response 1: Blocks execute their algorithm and check the result for ±NAN or ±INF. If ±NAN or ±INF, the block outputs ±NAN or ±INF.		**Response 2:** Blocks with output limiting execute their algorithm and check the result for ±NAN or ±INF. The output limits are defined by the HighLimit and LowLimit input parameters. If ±INF, the block outputs a limited result. If ±NAN, the output limits are not used and the block outputs ±NAN.	**Response 3:** The overflow condition does not apply. These instructions typically have a boolean output.	
ALM	NTCH	HLL	BAND	OSRI
DEDT	PMUL	INTG	BNOT	RESD
DERV	POSP	PI	BOR	RTOR
ESEL	RLIM	PIDE	BXOR	SETD
FGEN	RMPS	SCL	CUTD	TOFR
HPF	SCRV	SOC	D2SD	TONR
LDL2	SEL		D3SD	
LDLG	SNEG		DFF	
LPF	SRTP		JKFF	
MAVE	SSUM		OSFI	
MAXC	TOT			
MINC	UPDN			
MSTD				
MUX				

Timing Modes

These process control and drives instructions support different timing modes.

DEDT	LDLG	RLIM
DERV	LPF	SCRV
HPF	NTCH	SOC
INTG	PI	TOT
LDL2	PIDE	

There are three different timing modes:

<table>
<tr><th>Timing Mode:</th><th>Description:</th></tr>
<tr><td>periodic</td><td>Periodic mode is the default mode and is suitable for most control applications. We recommend that you place the instructions that use this mode in a routine that executes in a periodic task. The delta time (DeltaT) for the instruction is determined as follows:
<table>
<tr><th>If the instruction executes in a:</th><th>Then DeltaT equals:</th></tr>
<tr><td>periodic task</td><td>period of the task</td></tr>
<tr><td>event or continuous task</td><td>elapsed time since the previous execution

The controller truncates the elapsed time to whole milliseconds (ms). For example, if the elapsed time = 10.5 ms, the controller sets DeltaT = 10 ms.</td></tr>
</table>
The update of the process input needs to be synchronized with the execution of the task or sampled 5-10 times faster than the task executes in order to minimize the sampling error between the input and the instruction.</td></tr>
<tr><td>oversample</td><td>In oversample mode, the delta time (DeltaT) used by the instruction is the value written into the OversampleDT parameter of the instruction. If the process input has a time stamp value, use the real time sampling mode instead.

Add logic to your program to control when the instruction executes. For example, you can use a timer set to the OversampleDeltaT value to control the execution by using the EnableIn input of the instruction.

The process input needs to be sampled 5-10 times faster than the instruction is executed in order to minimize the sampling error between the input and the instruction.</td></tr>
<tr><td>real time sampling</td><td>In the real time sampling mode, the delta time (DeltaT) used by the instruction is the difference between two time stamp values that correspond to the updates of the process input. Use this mode when the process input has a time stamp associated with its updates and you need precise coordination.

The time stamp value is read from the tag name entered for the RTSTimeStamp parameter of the instruction. Normally this tag name is a parameter on the input module associated with the process input.

The instruction compares the configured RTSTime value (expected update period) against the calculated DeltaT to determine if every update of the process input is being read by the instruction. If DeltaT is not within 1 millisecond of the configuration time, the instruction sets the RTSMissed status bit to indicate that a problem exists reading updates for the input on the module.</td></tr>
</table>

Time-based instructions require a constant value for DeltaT in order for the control algorithm to properly calculate the process output. If DeltaT varies, a discontinuity occurs in the process output. The severity of the discontinuity depends on the instruction and range over which DeltaT varies. A discontinuity occurs if the:

- instruction is not executed during a scan.
- instruction is executed multiple times during a task.
- task is running and the task scan rate or the sample time of the process input changes.
- user changes the time base mode while the task is running.
- Order parameter is changed on a filter block while the task is running. Changing the Order parameter selects a different control algorithm within the instruction.

Common instruction parameters for timing modes

The instructions that support time base modes have these input and output parameters:

Input parameters

Input Parameter:	Data Type:	Description:
TimingMode	DINT	Selects timing execution mode. **Value:** **Description:** 0 periodic mode 1 oversample mode 2 real time sampling mode valid = 0 to 2 default = 0 When TimingMode = 0 and task is periodic, periodic timing is enabled and DeltaT is set to the task scan rate. When TimingMode = 0 and task is event or continuous, periodic timing is enabled and DeltaT is set equal to the elapsed time span since the last time the instruction was executed. When TimingMode = 1, oversample timing is enabled and DeltaT is set to the value of the OversampleDT parameter. When TimingMode = 2, real time sampling timing is enabled and DeltaT is the difference between the current and previous time stamp values read from the module associated with the input. If TimingMode invalid, the instruction sets the appropriate bit in Status.
OversampleDT	REAL	Execution time for oversample timing. The value used for DeltaT is in seconds. If TimingMode = 1, then OversampleDT = 0.0 disables the execution of the control algorithm. If invalid, the instruction sets DeltaT = 0.0 and sets the appropriate bit in Status. valid = 0 to 4194.303 seconds default = 0.0

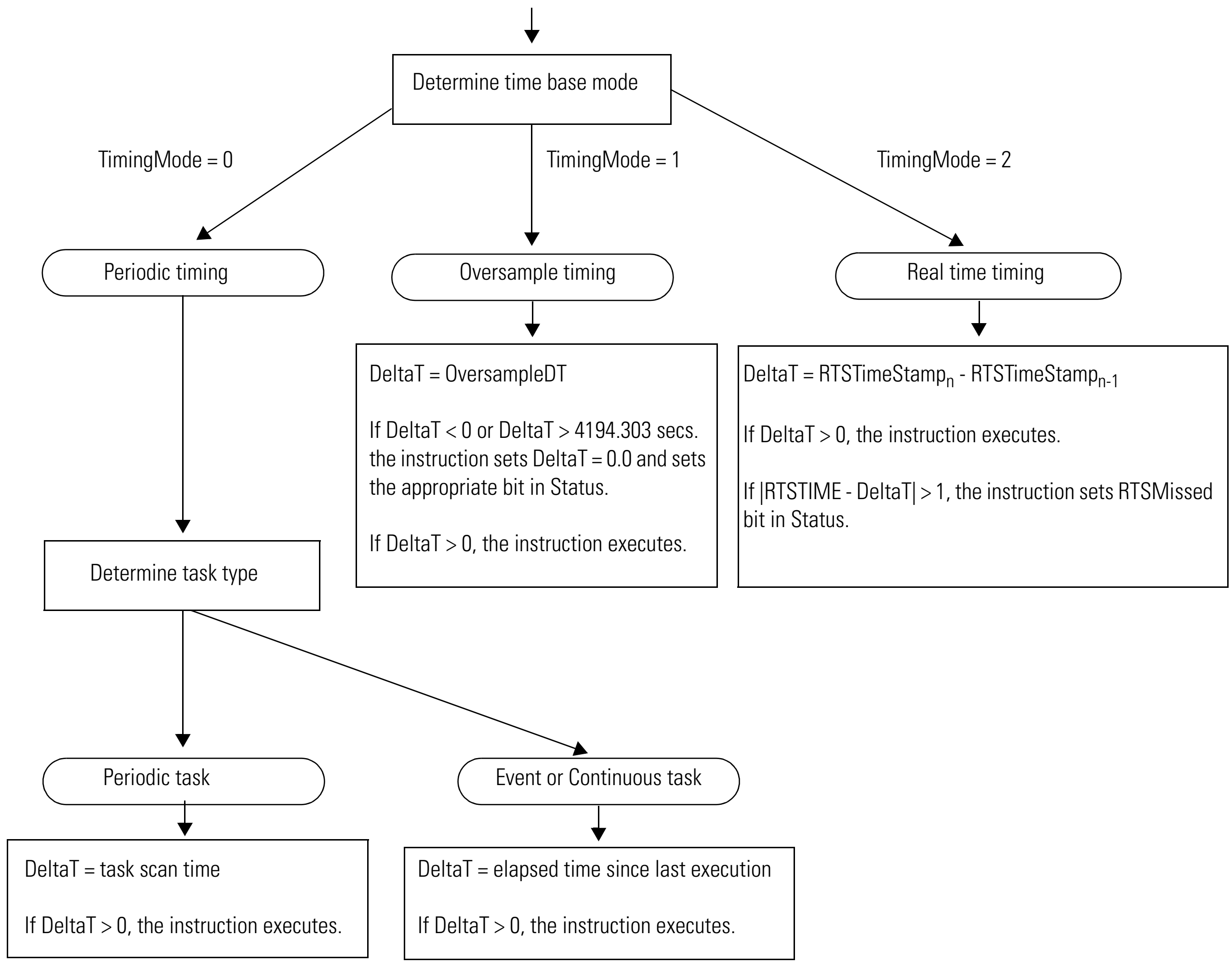
Input Parameter:	Data Type:	Description:
RTSTime	DINT	Module update period for real time sampling timing. The expected DeltaT update period is in milliseconds. The update period is normally the value that was used to configure the module's update time. If invalid, the instruction sets the appropriate bit in Status and disables RTSMissed checking. valid = 1 to 32,767ms default = 1
RTSTimeStamp	DINT	Module time stamp value for real time sampling timing. The time stamp value that corresponds to the last update of the input signal. This value is used to calculate DeltaT. If invalid, the instruction sets the appropriate bit in Status, disables execution of the control algorithm, and disables RTSMissed checking. valid =1 to 32,767ms (wraps from 32767 to 0) 1 count = 1 millisecond default = 0

Output parameters

Output Parameter:	Data Type:	Description:
DeltaT	REAL	Elapsed time between updates. This is the elapsed time in seconds used by the control algorithm to calculate the process output. Periodic: DeltaT = task scan rate if task is Periodic task, DeltaT = elapsed time since previous instruction execution if task is Event or Continuous task Oversample: DeltaT = OversampleDT Real Time Sampling: DeltaT = ($RTSTimeStamp_n$ - $RTSTimeStamp_{n-1}$)
Status	DINT	Status of the function block.
TimingModeInv (Status.27)	BOOL	Invalid TimingMode value.
RTSMissed (Status.28)	BOOL	Only used in real time sampling mode. Set when ABS | DeltaT - RTSTime | > 1 (.001 second).
RTSTimeInv (Status.29)	BOOL	Invalid RTSTime value.
RTSTimeStampInv (Status.30)	BOOL	Invalid RTSTimeStamp value.
DeltaTInv (Status.31)	BOOL	Invalid DeltaT value.

Overview of timing modes

The following diagram shows how an instruction determines the appropriate timing mode.



Program/Operator Control

Several instructions support the concept of Program/Operator control. These instructions include:

- Enhanced Select (ESEL)
- Totalizer (TOT)
- Enhanced PID (PIDE)
- Ramp/Soak (RMPS)
- Discrete 2-State Device (D2SD)
- Discrete 3-State Device (D3SD)

Program/Operator control lets you control these instructions simultaneously from both your user program and from an operator interface device. When in Program control, the instruction is controlled by the Program inputs to the instruction; when in Operator control, the instruction is controlled by the Operator inputs to the instruction.

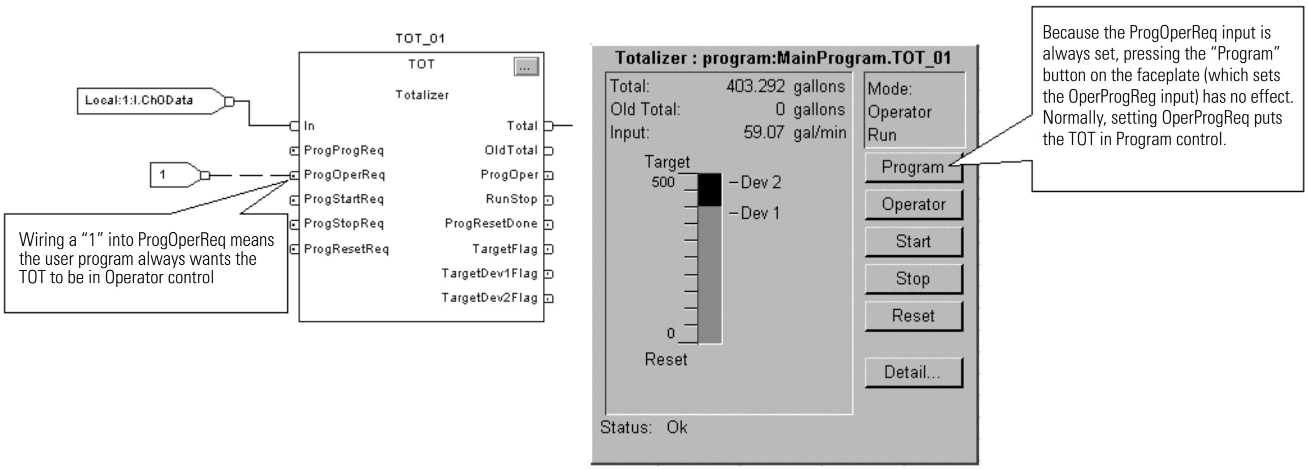
Program or Operator control is determined by using these inputs:

Input:	Description:
.ProgProgReq	A program request to go to Program control.
.ProgOperReq	A program request to go to Operator control.
.OperProgReq	An operator request to go to Program control.
.OperOperReq	An operator request to go to Operator control.

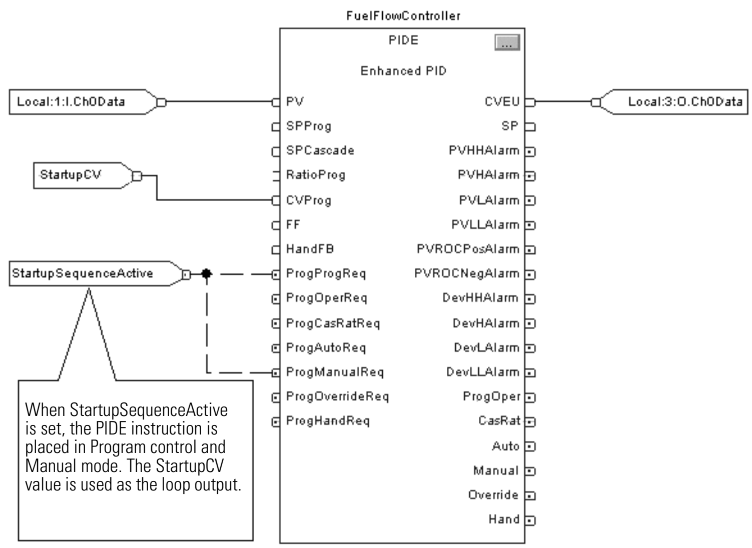
To determine whether an instruction is in Program or Control control, examine the ProgOper output. If ProgOper is set, the instruction is in Program control; if ProgOper is cleared, the instruction is in Operator control.

Operator control takes precedence over Program control if both input request bits are set. For example, if ProgProgReq and ProgOperReq are both set, the instruction goes to Operator control.

The Program request inputs take precedence over the Operator request inputs. This provides the capability to use the ProgProgReq and ProgOperReq inputs to “lock” an instruction in a desired control. For example, let’s assume that a Totalizer instruction will always be used in Operator control, and your user program will never control the running or stopping of the Totalizer. In this case, you could wire a literal value of 1 into the ProgOperReq. This would prevent the operator from ever putting the Totalizer into Program control by setting the OperProgReq from an operator interface device.



Likewise, constantly setting the ProgProgReq can “lock” the instruction into Program control. This is useful for automatic startup sequences when you want the program to control the action of the instruction without worrying about an operator inadvertently taking control of the instruction. In this example, you have the program set the ProgProgReq input during the startup, and then clear the ProgProgReq input once the startup was complete. Once the ProgProgReq input is cleared, the instruction remains in Program control until it receives a request to change. For example, the operator could set the OperOperReq input from a faceplate to take over control of that instruction. The following example shows how to lock an instruction into Program control.



Operator request inputs to an instruction are always cleared by the instruction when it executes. This allows operator interfaces to work with these instructions by merely setting the desired mode request bit. You don’t have to program the operator interface to reset the request bits. For example, if an operator interface sets the OperAutoReq input to a PIDE instruction, when the PIDE instruction executes, it determines what the appropriate response should be and clears the OperAutoReq.

Program request inputs are not normally cleared by the instruction because these are normally wired as inputs into the instruction. If the instruction clears these inputs, the input would just get set again by the wired input. There might be situations where you want to use other logic to set the Program requests in such a manner that you want the Program requests to be cleared by the instruction. In this case, you can set the ProgValueReset input and the instruction will always clear the Program mode request inputs when it executes.

In this example, a rung of ladder logic in another routine is used to one-shot latch a ProgAutoReq to a PIDE instruction when a pushbutton is pushed. Because the PIDE instruction automatically clears the Program mode requests, you don't have to write any ladder logic to clear the ProgAutoReq after the routine executes, and the PIDE instruction will receive only one request to go to Auto every time the pushbutton is pressed.

When the TIC101AutoReq Pushbutton is pressed, one-shot latch ProgAutoReq for the PIDE instruction TIC101. TIC101 has been configured with the ProgValueReset input set, so when the PIDE instruction executes, it automatically clears ProgAutoReq.

Structured Text Programming

Introduction

This appendix describes issues that are unique with structured text programming. Review the information in this appendix to make sure you understand how your structured text programming will execute.

Structured Text Syntax

Structured text is a textual programming language that uses statements to define what to execute. Structured text is not case sensitive. Structured text can contain these components:

Term:	Definition:		Examples:
assignment (see page C-3)	Use an assignment statement to assign values to tags. The := operator is the assignment operator. Terminate the assignment with a semi colon ";".		`tag := expression;`
expression (see page C-5)	An expression is part of a complete assignment or construct statement. An expression evaluates to a number (numerical expression) or to a true or false state (BOOL expression). An expression contains:		
	tags	A named area of the memory where data is stored (BOOL, SINT,INT,DINT, REAL, string).	`value1`
	immediates	A constant value.	`4`
	operators	A symbol or mnemonic that specifies an operation within an expression.	`tag1 + tag2` `tag1 >= value1`
	functions	When executed, a function yields one value. Use parentheses to contain the operand of a function. Even though their syntax is similar, functions differ from instructions in that functions can only be used in expressions. Instructions cannot be used in expressions.	`function(tag1)`

Term:	Definition:	Examples:
instruction (see page C-12)	An instruction is a standalone statement. An instruction uses parenthesis to contain its operands. Depending on the instruction, there can be zero, one, or multiple operands. When executed, an instruction yields one or more values that are part of a data structure. Terminate the instruction with a semi colon “;”. Even though their syntax is similar, instructions differ from functions in that instructions cannot be used in expressions. Functions can only be used in expressions.	*instruction();* *instruction(operand);* *instruction(operand1, operand2,operand3);*
construct (see page C-13)	A conditional statement used to trigger structured text code (i.e, other statements). Terminate the construct with a semi colon “;”.	IF...THEN CASE FOR...DO WHILE...DO REPEAT...UNTIL EXIT
comment (see page C-28)	Text that explains or clarifies what a section of structured text does. • Use comments to make it easier to interpret the structured text. • Comments do not affect the execution of the structured text. • Comments can appear anywhere in structured text.	*//comment* (*start of comment . . . end of comment*) */*start of comment . . . end of comment*/*

Entering spaces in structured text syntax is optional. Spaces have no effect on the execution of the structured text. For example, both of these statements execute the same:

Tag_B:=Tag_A

Tag_B := Tag_A

Assignments

Use an assignment to change the value stored within a tag. An assignment has this syntax:

`tag := expression ;`

where:

Component:	Description:	
tag	represents the tag that is getting the new value the tag must be a BOOL, SINT, INT, DINT, or REAL	
:=	is the assignment symbol	
expression	represents the new value to assign to the tag	
	If *tag* is this data type:	**Use this type of expression:**
	BOOL	BOOL expression
	SINT INT DINT REAL	numeric expression
;	ends the assignment	

The *tag* retains the assigned value until another assignment changes the value.

The expression can be simple, such as an immediate value or another tag name, or the expression can be complex and include several operators and/or functions. See the next section “Expressions“on page C-5 for details.

Specify a non-retentive assignment

The non-retentive assignment is different from the regular assignment described above in that the tag in a non-retentive assignment is reset to zero each time the controller:

- enters the RUN mode
- leaves the step of an SFC if you configure the SFC for Automatic reset (This applies only if you embed the assignment in the action of the step or use the action to call a structured text routine via a JSR instruction.)

A non-retentive assignment has this syntax:

`tag` [:=] `expression` ;

where:

Component:	Description:	
`tag`	represents the tag that is getting the new value the tag must be a BOOL, SINT, INT, DINT, or REAL	
[:=]	is the non-retentive assignment symbol	
`expression`	represents the new value to assign to the tag	
	If `tag` is this data type:	**Use this type of expression:**
	BOOL	BOOL expression
	SINT INT DINT REAL	numeric expression
;	ends the assignment	

Assign an ASCII character to a string

Use the assignment operator to assign an ASCII character to an element of the DATA member of a string tag. To assign a character, specify the value of the character or specify the tag name, DATA member, and element of the character. For example:

This is OK:	This is *not* OK.
`string1.DATA[0]:= 65;`	`string1.DATA[0] := A;`
`string1.DATA[0]:= string2.DATA[0];`	`string1 := string2;`

To add or insert a string of characters to a string tag, use either of these ASCII string instructions:

To:	Use this instruction:
add characters to the end of a string	CONCAT
insert characters into a string	INSERT

Expressions

An expression is a tag name, equation, or comparison. To write an expression, use any of the following:

- tag name that stores the value (variable)
- number that you enter directly into the expression (immediate value)
- functions, such as: ABS, TRUNC
- operators, such as: +, -, <, >, And, Or

As you write expressions, follow these general rules:

- Use any combination of upper-case and lower-case letter. For example, these three variations of "AND" are acceptable: AND, And, and.
- For more complex requirements, use parentheses to group expressions within expressions. This makes the whole expression easier to read and ensures that the expression executes in the desired sequence. See "Determine the order of execution"on page C-11.

In structured text, you use two types of expressions:

BOOL expression: An expression that produces either the BOOL value of 1 (true) or 0 (false).

- A bool expression uses bool tags, relational operators, and logical operators to compare values or check if conditions are true or false. For example, tag1>65.
- A simple bool expression can be a single BOOL tag.
- Typically, you use bool expressions to condition the execution of other logic.

Numeric expression: An expression that calculates an integer or floating-point value.

- A numeric expression uses arithmetic operators, arithmetic functions, and bitwise operators. For example, tag1+5.
- Often, you nest a numeric expression within a bool expression. For example, (tag1+5)>65.

Use the following table to choose operators for your expressions:

If you want to:	Then:
Calculate an arithmetic value	"Use arithmetic operators and functions"on page C-7.
Compare two values or strings	"Use relational operators"on page C-8.
Check if conditions are true or false	"Use logical operators"on page C-10.
Compare the bits within values	"Use bitwise operators"on page C-11.

Use arithmetic operators and functions

You can combine multiple operators and functions in arithmetic expressions.

Arithmetic operators calculate new values.

To:	Use this operator:	Optimal data type:
add	+	DINT, REAL
subtract/negate	-	DINT, REAL
multiply	*	DINT, REAL
exponent (x to the power of y)	**	DINT, REAL
divide	/	DINT, REAL
modulo-divide	MOD	DINT, REAL

Arithmetic functions perform math operations. Specify a constant, a non-boolean tag, or an expression for the function.

For:	Use this function:	Optimal data type:
absolute value	ABS (*numeric_expression*)	DINT, REAL
arc cosine	ACOS (*numeric_expression*)	REAL
arc sine	ASIN (*numeric_expression*)	REAL
arc tangent	ATAN (*numeric_expression*)	REAL
cosine	COS (*numeric_expression*)	REAL
radians to degrees	DEG (*numeric_expression)*	DINT, REAL
natural log	LN (*numeric_expression*)	REAL
log base 10	LOG (*numeric_expression*)	REAL
degrees to radians	RAD (*numeric_expression*)	DINT, REAL
sine	SIN (*numeric_expression*)	REAL
square root	SQRT (*numeric_expression*)	DINT, REAL
tangent	TAN (*numeric_expression*)	REAL
truncate	TRUNC (*numeric_expression*)	DINT, REAL

For example:

Use this format:	Example:	
	For this situation:	**You'd write:**
value1 operator value2	If *gain_4* and *gain_4_adj* are DINT tags and your specification says: "Add 15 to *gain_4* and store the result in *gain_4_adj*."	`gain_4_adj := gain_4+15;`
operator value1	If alarm and *high_alarm* are DINT tags and your specification says: "Negate *high_alarm* and store the result in *alarm*."	`alarm:= -high_alarm;`
function(numeric_expression)	If *overtravel* and *overtravel_POS* are DINT tags and your specification says: "Calculate the absolute value of *overtravel* and store the result in *overtravel_POS*."	`overtravel_POS := ABS(overtravel);`
value1 operator (function((value2+value3)/2)	If *adjustment* and *position* are DINT tags and *sensor1* and *sensor2* are REAL tags and your specification says: "Find the absolute value of the average of *sensor1* and *sensor2*, add the *adjustment*, and store the result in *position*."	`position := adjustment + ABS((sensor1 + sensor2)/2);`

Use relational operators

Relational operators compare two values or strings to provide a true or false result. The result of a relational operation is a BOOL value:

If the comparison is:	The result is:
true	1
false	0

Use the following relational operators:

For this comparison:	Use this operator:	Optimal Data Type:
equal	=	DINT, REAL, string
less than	<	DINT, REAL, string
less than or equal	<=	DINT, REAL, string
greater than	>	DINT, REAL, string
greater than or equal	>=	DINT, REAL, string
not equal	<>	DINT, REAL, string

For example:

Use this format:	Example:	
	For this situation:	**You'd write:**
value1 operator value2	If *temp* is a DINT tag and your specification says: "If *temp* is less than 100° then…"	`IF temp<100 THEN...`
stringtag1 operator stringtag2	If *bar_code* and *dest* are string tags and your specification says: "If *bar_code* equals *dest* then…"	`IF bar_code=dest THEN...`
char1 operator char2 To enter an ASCII character directly into the expression, enter the decimal value of the character.	If *bar_code* is a string tag and your specification says: "If *bar_code.DATA[0]* equals 'A' then…"	`IF bar_code.DATA[0]=65 THEN...`
bool_tag := bool_expressions	If *count* and *length* are DINT tags, *done* is a BOOL tag, and your specification says "If *count* is greater than or equal to *length*, you are done counting."	`done := (count >= length);`

How Strings Are Evaluated

The hexadecimal values of the ASCII characters determine if one string is less than or greater than another string.

- When the two strings are sorted as in a telephone directory, the order of the strings determines which one is greater.

lesser ↑ greater ↓

ASCII Characters	Hex Codes
1ab	$31$61$62
1b	$31$62
A	$41
AB	$41$42
B	$42
a	$61
ab	$61$62

AB < B

a > B

- Strings are equal if their characters match.
- Characters are case sensitive. Upper case "A" ($41) is not equal to lower case "a" ($61).

For the decimal value and hex code of a character, see the back cover of this manual.

Use logical operators

Logical operators let you check if multiple conditions are true or false. The result of a logical operation is a BOOL value:

If the comparison is:	The result is:
true	1
false	0

Use the following logical operators:

For:	Use this operator:	Data Type:
logical AND	&, AND	BOOL
logical OR	OR	BOOL
logical exclusive OR	XOR	BOOL
logical complement	NOT	BOOL

For example:

Use this format:	Example:	
	For this situation:	**You'd write:**
`BOOLtag`	If *photoeye* is a BOOL tag and your specification says: "If *photoeye_1* is on then…"	`IF photoeye THEN...`
NOT `BOOLtag`	If *photoeye* is a BOOL tag and your specification says: "If *photoeye* is off then…"	`IF NOT photoeye THEN...`
`expression1` & `expression2`	If *photoeye* is a BOOL tag, *temp* is a DINT tag, and your specification says: "If *photoeye* is on and *temp* is less than 100° then…".	`IF photoeye & (temp<100) THEN...`
`expression1` OR `expression2`	If *photoeye* is a BOOL tag, *temp* is a DINT tag, and your specification says: "If *photoeye* is on or *temp* is less than 100° then…".	`IF photoeye OR (temp<100) THEN...`
`expression1` XOR `expression2`	If *photoeye1* and *photoeye2* are BOOL tags and your specification says: "If: • *photoeye1* is on while *photoeye2* is off or • *photoeye1* is off while *photoeye2* is on then…"	`IF photoeye1 XOR photoeye2 THEN...`
`BOOLtag := expression1 & expression2`	If *photoeye1* and *photoeye2* are BOOL tags, *open* is a BOOL tag, and your specification says: "If *photoeye*1 and *photoeye2* are both on, set *open* to true".	`open := photoeye1 & photoeye2;`

Use bitwise operators

Bitwise operators manipulate the bits within a value based on two values.

For:	Use this operator:	Optimal Data Type:
bitwise AND	&, AND	DINT
bitwise OR	OR	DINT
bitwise exclusive OR	XOR	DINT
bitwise complement	NOT	DINT

For example:

Use this format:	Example:	
	For this situation:	You'd write:
`value1 operator value2`	If *input1*, *input2*, and *result1* are DINT tags and your specification says: "Calculate the bitwise result of *input1* and *input2*. Store the result in *result1*."	`result1 := input1 AND input2;`

Determine the order of execution

The operations you write into an expression are performed in a prescribed order, not necessarily from left to right.

- Operations of equal order are performed from left to right.
- If an expression contains multiple operators or functions, group the conditions in parenthesis "( )" . This ensures the correct order of execution and makes it easier to read the expression.

Order:	Operation:
1.	( )
2.	function (…)
3.	**
4.	– (negate)
5.	NOT
6.	*, /, MOD
7.	+, - (subtract)
8.	<, <=, >, >=
9.	=, <>
10.	&, AND
11.	XOR
12.	OR

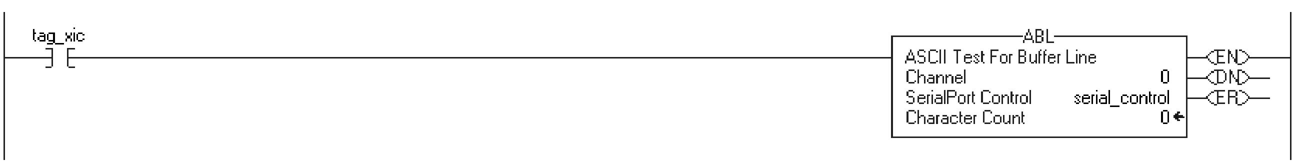
Instructions

Structured text statements can also be instructions. See the Locator Table at the beginning of this manual for a list of the instructions available in structured text. A structured text instruction executes each time it is scanned. A structured text instruction within a construct executes every time the conditions of the construct are true. If the conditions of the construct are false, the statements within the construct are not scanned. There is no rung-condition or state transition that triggers execution.

This differs from function block instructions that use EnableIn to trigger execution. Structured text instructions execute as if EnableIn is always set.

This also differs from relay ladder instructions that use rung-condition-in to trigger execution. Some relay ladder instructions only execute when rung-condition-in toggles from false to true. These are transitional relay ladder instructions. In structured text, instructions will execute each time they are scanned unless you pre-condition the execution of the structured text instruction.

For example, the ABL instruction is a transitional instruction in relay ladder. In this example, the ABL instruction only executes on a scan when tag_xic transitions from cleared to set. The ABL instruction does not execute when tag_xic stays set or when *tag_xic* is cleared.



In structured text, if you write this example as:

```
IF tag_xic THEN ABL(0,serial_control);

END_IF;
```

the ABL instruction will execute every scan that tag_xic is set, not just when tag_xic transitions from cleared to set.

If you want the ABL instruction to execute only when tag_xic transitions from cleared to set, you have to condition the structured text instruction. Use a one shot to trigger execution.

```
osri_1.InputBit := tag_xic;
OSRI(osri_1);

IF (osri_1.OutputBit) THEN
     ABL(0,serial_control);
END_IF;
```

Constructs

Constructs can be programmed singly or nested within other constructs.

If you want to:	Use this construct:	Available in these languages:	See page:
do something if or when specific conditions occur	IF...THEN	structured text	C-14
select what to do based on a numerical value	CASE...OF	structured text	C-17
do something a specific number of times before doing anything else	FOR...DO	structured text	C-19
keep doing something as long as certain conditions are true	WHILE...DO	structured text	C-22
keep doing something until a condition is true	REPEAT...UNTIL	structured text	C-25

Some key words are reserved for future use

These constructs are not available:

- GOTO
- REPEAT

RSLogix 5000 software will not let you use them.

IF...THEN

Use IF…THEN to do something if or when specific conditions occur.

Operands:

```
IF bool_expression THEN
    <statement>;
END_IF;
```

Structured Text

Operand:	Type:	Format:	Enter:
bool_ expression	BOOL	tag expression	BOOL tag or expression that evaluates to a BOOL value (BOOL expression)

Description:

The syntax is:

```
IF bool_expression1 THEN
    <statement >;          <- statements to execute when bool_expression1 is true
        .
        .
        .
ELSIF bool_expression2 THEN          (optional)
    <statement>;           <- statements to execute when bool_expression2 is true
        .
        .
        .
ELSE                                 (optional)
    <statement>;           <- statements to execute when both expressions are false
        .
        .
        .
END_IF;
```

To use ELSIF or ELSE, follow these guidelines:

1. To select from several possible groups of statements, add one or more ELSIF statements.
    - Each ELSIF represents an alternative path.
    - Specify as many ELSIF paths as you need.
    - The controller executes the first true IF or ELSIF and skips the rest of the ELSIFs and the ELSE.
2. To do something when all of the IF or ELSIF conditions are false, add an ELSE statement.

The following table summarizes different combinations of IF, THEN, ELSIF, and ELSE.

If you want to:	And:	Then use this construct
do something if or when conditions are true	do nothing if conditions are false	IF…THEN
	do something else if conditions are false	IF…THEN…ESLE
choose from alternative statements (or groups of statements) based on input conditions	do nothing if conditions are false	IF…THEN…ELSIF
	assign default statements if all conditions are false	IF…THEN…ELSIF…ELSE

Example 1: IF…THEN

If you want this:	Enter this structured text:
IF rejects > 3 then	`IF rejects > 3 THEN`
conveyor = off (0)	`conveyor := 0;`
alarm = on (1)	`alarm := 1;`
	`END_IF;`

Example 2: IF…THEN…ELSE

If you want this:	Enter this structured text:
If conveyor direction contact = forward (1) then	`IF conveyor_direction THEN`
light = off	`light := 0;`
Otherwise light = on	`ELSE`
	`light [:=] 1;`
	`END_IF;`

The [:=] tells the controller to clear light whenever the controller:

- enters the RUN mode
- leaves the step of an SFC if you configure the SFC for Automatic reset (This applies only if you embed the assignment in the action of the step or use the action to call a structured text routine via a JSR instruction.)

Example 3: IF…THEN…ELSIF

If you want this:	Enter this structured text:
If sugar low limit switch = low (on) and sugar high limit switch = not high (on) then	`IF Sugar.Low & Sugar.High THEN`
inlet valve = open (on)	`Sugar.Inlet [:=] 1;`
Until sugar high limit switch = high (off)	`ELSIF NOT(Sugar.High) THEN`
	`Sugar.Inlet := 0;`
	`END_IF;`

The [:=] tells the controller to clear Sugar.Inlet whenever the controller:

- enters the RUN mode
- leaves the step of an SFC if you configure the SFC for Automatic reset (This applies only if you embed the assignment in the action of the step or use the action to call a structured text routine via a JSR instruction.)

Example 4: IF…THEN…ELSIF…ELSE

If you want this:	Enter this structured text:
If tank temperature > 100	`IF tank.temp > 200 THEN`
then pump = slow	`pump.fast :=1; pump.slow :=0; pump.off :=0;`
If tank temperature > 200	`ELSIF tank.temp > 100 THEN`
then pump = fast	`pump.fast :=0; pump.slow :=1; pump.off :=0;`
otherwise pump = off	`ELSE`
	`pump.fast :=0; pump.slow :=0; pump.off :=1;`
	`END_IF;`

CASE...OF

Use CASE to select what to do based on a numerical value.

```
CASE numeric_expression OF
    selector1: statement;
    selectorN: statement;
ELSE
    statement;
END_CASE;
```

Operands:

Structured Text

Operand:	Type:	Format:	Enter:
numeric_ expression	SINT INT DINT REAL	tag expression	tag or expression that evaluates to a number (numeric expression)
selector	SINT INT DINT REAL	immediate	same type as *numeric_expression*

IMPORTANT If you use REAL values, use a range of values for a selector because a REAL value is more likely to be within a range of values than an exact match of one, specific value.

Description:

The syntax is:

```
CASE numeric_expression OF
    selector1 :  <statement>;   statements to execute when numeric_expression = selector1
                      .
                      .
                      .
    selector2 :  <statement>;   statements to execute when numeric_expression = selector2
                      .
                      .
                      .
    selector3 :  <statement>;   statements to execute when numeric_expression = selector3
                      .
                      .
                      .
ELSE
                 <statement>;   statements to execute when numeric_expression ≠ any selector
                      .
                      .
                      .
END_CASE;
```

specify as many alternative selector values (paths) as you need

optional

See the table on the next page for valid selector values.

The syntax for entering the selector values is:

When selector is:	Enter:
one value	*value*: *statement*
multiple, distinct values	*value1*, *value2*, *valueN* : <*statement*> Use a comma (,) to separate each value.
a range of values	*value1*..*valueN* : <*statement*> Use two periods (..) to identify the range.
distinct values plus a range of values	*valuea, valueb, value1*..*valueN* : <*statement*>

Example

If you want this:	Enter this structured text:
If recipe number = 1 then	`CASE recipe_number OF`
Ingredient A outlet 1 = open (1)	`1:        Ingredient_A.Outlet_1 :=1;`
Ingredient B outlet 4 = open (1)	`Ingredient_B.Outlet_4 :=1;`
If recipe number = 2 or 3 then	`2,3:      Ingredient_A.Outlet_4 :=1;`
Ingredient A outlet 4 = open (1)	`Ingredient_B.Outlet_2 :=1;`
Ingredient B outlet 2 = open (1)	
If recipe number = 4, 5, 6, or 7 then	`4..7:     Ingredient_A.Outlet_4 :=1;`
Ingredient A outlet 4 = open (1)	`Ingredient_B.Outlet_2 :=1;`
Ingredient B outlet 2 = open (1)	
If recipe number = 8, 11, 12, or 13 then	`8,11..13  Ingredient_A.Outlet_1 :=1;`
Ingredient A outlet 1 = open (1)	`Ingredient_B.Outlet_4 :=1;`
Ingredient B outlet 4 = open (1)	
Otherwise all outlets = closed (0)	`ELSE`
	`Ingredient_A.Outlet_1 [:=]0;`
	`Ingredient_A.Outlet_4 [:=]0;`
	`Ingredient_B.Outlet_2 [:=]0;`
	`Ingredient_B.Outlet_4 [:=]0;`
	`END_CASE;`

The [:=] tells the controller to also clear the outlet tags whenever the controller:

- enters the RUN mode
- leaves the step of an SFC if you configure the SFC for Automatic reset (This applies only if you embed the assignment in the action of the step or use the action to call a structured text routine via a JSR instruction.)

FOR…DO

Use the FOR…DO loop to do something a specific number of times before doing anything else.

Operands:

```
FOR count:= initial_value TO
final_value BY increment DO
    <statement>;
END_FOR;
```

Structured Text

Operand:	Type:	Format:	Description:
count	SINT INT DINT	tag	tag to store count position as the FOR…DO executes
initial_ value	SINT INT DINT	tag expression immediate	must evaluate to a number specifies initial value for count
final_ value	SINT INT DINT	tag expression immediate	specifies final value for count, which determines when to exit the loop
increment	SINT INT DINT	tag expression immediate	(*optional*) amount to increment count each time through the loop If you don't specify an increment, the count increments by 1.

IMPORTANT Make sure that you do not iterate within the loop too many times in a single scan.

- The controller does not execute any other statements in the routine until it completes the loop.
- If the time that it takes to complete the loop is greater than the watchdog timer for the task, a major fault occurs.
- Consider using a different construct, such as IF...THEN.

Description:

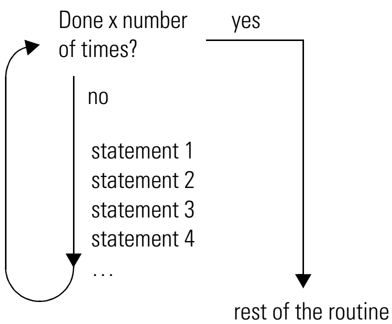
The syntax is:

```
FOR count := initial_value
   TO final_value
   BY increment                    (optional)
   DO
   <statement>;
   IF bool_expression THEN         (optional)
      EXIT;
   END_IF;
END_FOR;
```

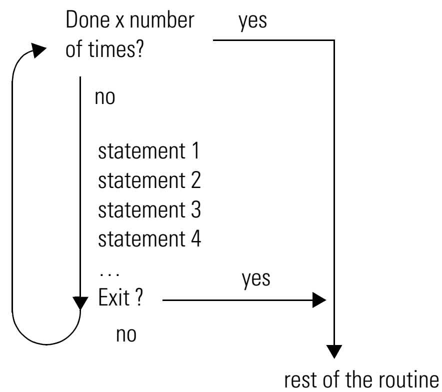
optional: BY *increment* — If you don't specify an increment, the loop increments by 1.

optional: IF … EXIT; END_IF; — If there are conditions when you want to exit the loop early, use other statements, such as an IF...THEN construct, to condition an EXIT statement.

The following diagrams show how a FOR...DO loop executes and how an EXIT statement leaves the loop early.



The FOR…DO loop executes a specific number of times.



To stop the loop before the count reaches the last value, use an EXIT statement.

Example 1:

If you want this:	Enter this structured text:

Clear bits 0 - 31 in an array of BOOLs:
1. Initialize the *subscript* tag to 0.
2. Clear *array[subscript]* . For example, when *subscript* = 5, clear *array[5].*
3. Add 1 to *subscript*.
4. If *subscript* is ≤ to 31, repeat 2 and 3. Otherwise, stop.
	`For subscript:=0 to 31 by 1 do`
	`array[subscript] := 0;`
	`End_for;`

Example 2:

If you want this:	Enter this structured text:

A user-defined data type (structure) stores the following information about an item in your inventory:
• Barcode ID of the item (string data type)
• Quantity in stock of the item (DINT data type)
An array of the above structure contains an element for each different item in your inventory. You want to search the array for a specific product (use its bar code) and determine the quantity that is in stock.
1. Get the size (number of items) of the *Inventory* array and store the result in *Inventory_Items* (DINT tag).
2. Initialize the *position* tag to 0.
3. If *Barcode* matches the ID of an item in the array, then:
a. Set the *Quantity* tag = *Inventory[position].Qty*. This produces the quantity in stock of the item.
b. Stop.
Barcode is a string tag that stores the bar code of the item for which you are searching. For example, when *position* = 5, compare *Barcode* to *Inventory[5].ID.*
4. Add 1 to *position*.
5. If *position* is ≤ to (*Inventory_Items -1)*, repeat 3 and 4. Since element numbers start at 0, the last element is 1 less than the number of elements in the array. Otherwise, stop.
	`SIZE(Inventory,0,Inventory_Items);`
	`For position:=0 to Inventory_Items - 1 do`
	`    If Barcode = Inventory[position].ID then`
	`        Quantity := Inventory[position].Qty;`
	`        Exit;`
	`    End_if;`
	`End_for;`

WHILE…DO

Use the WHILE…DO loop to keep doing something as long as certain conditions are true.

Operands:

```
WHILE bool_expression DO
    <statement>;
END_WHILE;
```

Structured Text

Operand:	Type:	Format:	Enter:
bool_ expression	BOOL	tag expression	BOOL tag or expression that evaluates to a BOOL value

IMPORTANT Make sure that you do not iterate within the loop too many times in a single scan.

- The controller does not execute any other statements in the routine until it completes the loop.
- If the time that it takes to complete the loop is greater than the watchdog timer for the task, a major fault occurs.
- Consider using a different construct, such as IF...THEN.

Description:

The syntax is:

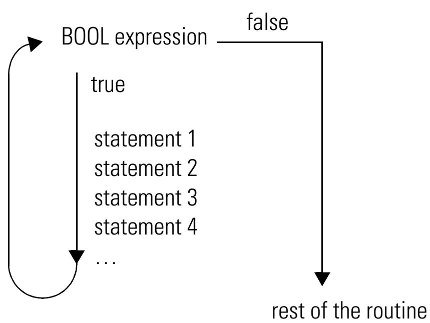
```
WHILE bool_expression1 DO
   <statement>;

   IF bool_expression2 THEN
     EXIT;
   END_IF;

END_WHILE;
```

statements to execute while *bool_expression1* is true

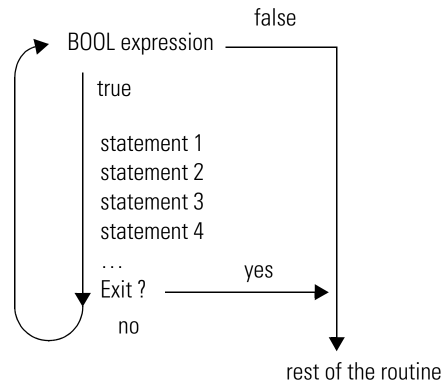
optional

If there are conditions when you want to exit the loop early, use other statements, such as an IF...THEN construct, to condition an EXIT statement.

The following diagrams show how a WHILE...DO loop executes and how an EXIT statement leaves the loop early.



While the *bool_expression* is true, the controller executes only the statements within the WHILE…DO loop.



To stop the loop before the conditions are true, use an EXIT statement.

Example 1:

If you want this:	Enter this structured text:

The WHILE...DO loop evaluates its conditions first. If the conditions are true, the controller then executes the statements within the loop.
 	
This differs from the REPEAT...UNTIL loop because the REPEAT...UNTIL loop executes the statements in the construct and then determines if the conditions are true before executing the statements again. The statements in a REPEAT...UNTIL loop are always executed at least once. The statements in a WHILE...DO loop might never be executed.
	`pos := 0;`
	
	`While ((pos <= 100) & structarray[pos].value <> targetvalue)) do`
	
	`    pos := pos + 2;`
	
	`    String_tag.DATA[pos] := SINT_array[pos];`
	
	`end_while;`

Example 2:

If you want this:	Enter this structured text:

Move ASCII characters from a SINT array into a string tag. (In a SINT array, each element holds one character.) Stop when you reach the carriage return.
1. Initialize *Element_number* to 0.
2. Count the number of elements in *SINT_array* (array that contains the ASCII characters) and store the result in *SINT_array_size* (DINT tag).
3. If the character at *SINT_array[element_number]* = 13 (decimal value of the carriage return), then stop.
4. Set *String_tag[element_number]* = the character at *SINT_array[element_number]*.
5. Add 1 to *element_number*. This lets the controller check the next character in *SINT_array*.
6. Set the Length member of *String_tag* = *element_number*. (This records the number of characters in *String_tag* so far.)
7. If *element_number* = *SINT_array_size,* then stop. (You are at the end of the array and it does not contain a carriage return.)
8. Go to 3.
	`element_number := 0;`
	`SIZE(SINT_array, 0, SINT_array_size);`
	`While SINT_array[element_number] <> 13 do`
	`    String_tag.DATA[element_number] :=`
	`    SINT_array[element_number];`
	`    element_number := element_number + 1;`
	`    String_tag.LEN := element_number;`
	`    If element_number = SINT_array_size then`
	`        exit;`
	`    end_if;`
	`end_while;`

REPEAT…UNTIL

Use the REPEAT…UNTIL loop to keep doing something until conditions are true.

```
REPEAT
    <statement>;
UNTIL bool_expression
END_REPEAT;
```

Operands:

Structured Text

Operand:	Type:	Format:	Enter:
bool_ expression	BOOL	tag expression	BOOL tag or expression that evaluates to a BOOL value (BOOL expression)

IMPORTANT Make sure that you do not iterate within the loop too many times in a single scan.

- The controller does not execute any other statements in the routine until it completes the loop.
- If the time that it takes to complete the loop is greater than the watchdog timer for the task, a major fault occurs.
- Consider using a different construct, such as IF...THEN.

Description:

The syntax is:

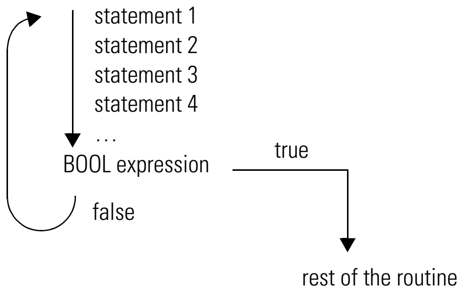
```
REPEAT
   <statement>;

   IF bool_expression2 THEN
     EXIT;
   END_IF;

UNTIL bool_expression1
END_REPEAT;
```

statements to execute while *bool_expression1* is false

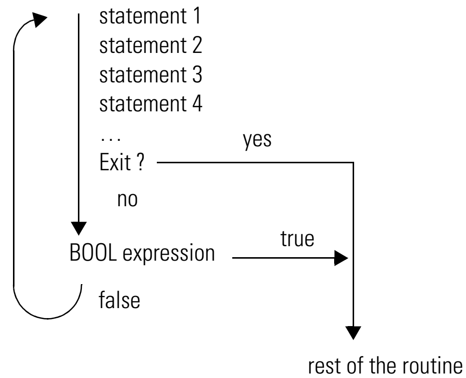
optional

If there are conditions when you want to exit the loop early, use other statements, such as an IF...THEN construct, to condition an EXIT statement.

The following diagrams show how a REPEAT...UNTIL loop executes and how an EXIT statement leaves the loop early.



While the *bool_expression* is false, the controller executes only the statements within the REPEAT…UNTIL loop.



To stop the loop before the conditions are false, use an EXIT statement.

Example 1:

If you want this:	Enter this structured text:

The REPEAT...UNTIL loop executes the statements in the construct and then determines if the conditions are true before executing the statements again.
This differs from the WHILE...DO loop because the WHILE...DO The WHILE...DO loop evaluates its conditions first. If the conditions are true, the controller then executes the statements within the loop. The statements in a REPEAT...UNTIL loop are always executed at least once. The statements in a WHILE...DO loop might never be executed.
	`pos := -1;`
	`REPEAT`
	`    pos := pos + 2;`
	`UNTIL ((pos = 101) OR (structarray[pos].value = targetvalue))`
	`end_repeat;`

Example 2:

<table>
<tr><th>If you want this:</th><th>Enter this structured text:</th></tr>
<tr><td>Move ASCII characters from a SINT array into a string tag. (In a SINT array, each element holds one character.) Stop when you reach the carriage return.
1. Initialize Element_number to 0.
2. Count the number of elements in SINT_array (array that contains the ASCII characters) and store the result in SINT_array_size (DINT tag).
3. Set String_tag[element_number] = the character at SINT_array[element_number].
4. Add 1 to element_number. This lets the controller check the next character in SINT_array.
5. Set the Length member of String_tag = element_number. (This records the number of characters in String_tag so far.)
6. If element_number = SINT_array_size, then stop. (You are at the end of the array and it does not contain a carriage return.)
7. If the character at SINT_array[element_number] = 13 (decimal value of the carriage return), then stop. Otherwise, go to 3.</td><td><pre>element_number := 0;
SIZE(SINT_array, 0, SINT_array_size);
Repeat
    String_tag.DATA[element_number] :=
    SINT_array[element_number];
    element_number := element_number + 1;
    String_tag.LEN := element_number;
    If element_number = SINT_array_size then
        exit;
    end_if;
Until SINT_array[element_number] = 13
end_repeat;</pre></td></tr>
</table>

Comments

To make your structured text easier to interpret, add comments to it.

- Comments let you use plain language to describe how your structured text works.
- Comments do not affect the execution of the structured text.

To add comments to your structured text:

To add a comment:	Use one of these formats:
on a single line	*//comment*
at the end of a line of structured text	(**comment**) */*comment*/*
within a line of structured text	(**comment**) */*comment*/*
that spans more than one line	(**start of comment . . . end of comment**) */*start of comment . . . end of comment*/*

For example:

Format:	Example:

//comment	**At the beginning of a line**
	`//Check conveyor belt direction`
	`IF conveyor_direction THEN...`
	At the end of a line
	`ELSE //If conveyor isn’t moving, set alarm light`
	`light := 1;`
	`END_IF;`

(**comment**)	`Sugar.Inlet[:=]1;(*open the inlet*)`
	`IF Sugar.Low (*low level LS*)& Sugar.High (*high level LS*)THEN...`
	`(*Controls the speed of the recirculation pump. The speed depends on the temperature in the tank.*)`
	`IF tank.temp > 200 THEN...`

*/*comment*/*	`Sugar.Inlet:=0;/*close the inlet*/`
	`IF bar_code=65 /*A*/ THEN...`
	`/*Gets the number of elements in the Inventory array and stores the value in the Inventory_Items tag*/`
	`SIZE(Inventory,0,Inventory_Items);`

Function Block Faceplate Controls

Introduction

RSLogix 5000 programming software includes faceplates (controls) for some of the function block instructions. These faceplates are Active-X controls that you can use in RSView SE or RSView32 software or any other application that can act as an Active-X container. In the case of RSView SE software, the faceplates communicate with the controller via RSLinx Enterprise software. In the case of RSView 32 or other third-party applications, the faceplates communicate with the controller via the RSLinx OPC server.

IMPORTANT RSLogix 5000 programming software cannot be a container for the faceplates. You must use software such as RSView SE or RSView 32 software as a container for the faceplates.

These instructions have faceplates:

Instruction:	See page:
Alarm (ALM)	D-6
Enhanced Select (ESEL)	D-8
Totalizer (TOT)	D-9
Ramp/Soak (RMPS)	D-11
Discrete 2-State Device (D2SD)	D-14
Discrete 3-State Device (D3SD)	D-16
Enhanced PID (PIDE)	D-18

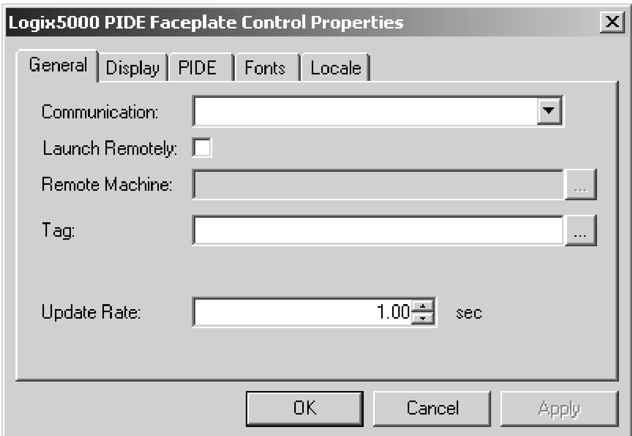
You configure the faceplates through property pages that you open through the container application, such as RSView SE or RSView32 software.

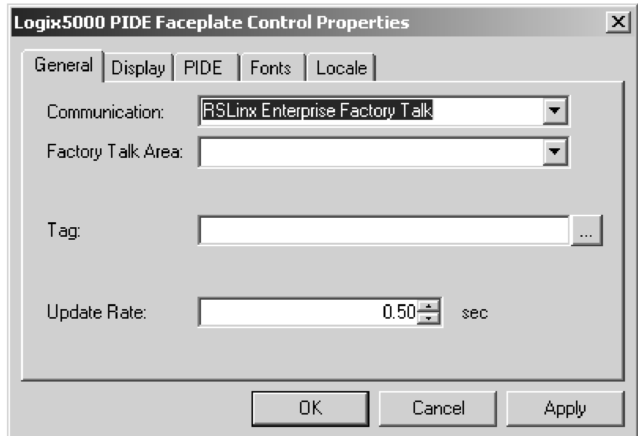
All faceplates have four property pages in common.

- general
- display
- server
- fonts

Configuring general properties

The general property page determines how the control operates.





Feature on property page:	Description:
Communication	Select RSLinx Classic OPC Server or RSLinx Enterprise Factory Talk. If you select RSLinx Classis OPC Server, you must also specify: • whether to launch remotely • the access path to the remote machine If you select RSLinx Enterprise Factory Talk, you must also specify: • the Factory Talk Area
Tag	Specify the function block instruction to connect to this control.
Update Rate	This option configures the Update Rate of the control in seconds. Use the spin control to modify the rate in increments of 0.25 seconds. default = 1.00 seconds

IMPORTANT

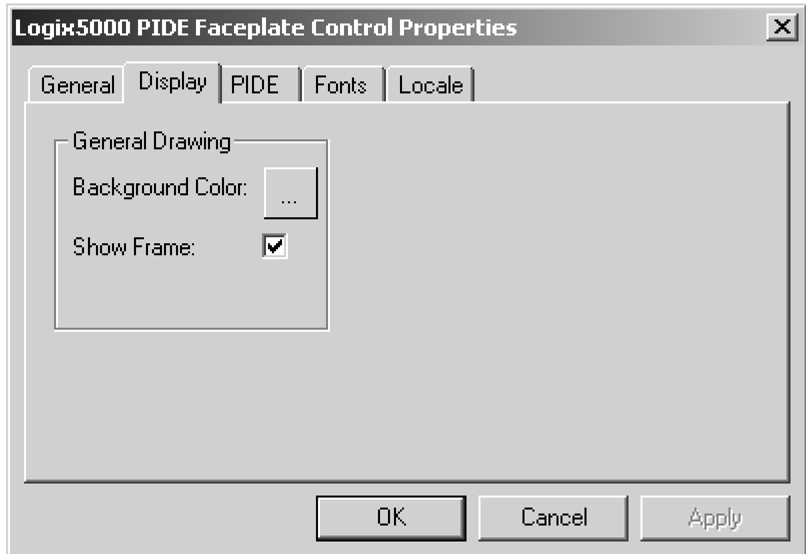
The example Block Tag in the screen above shows a controller-scoped tag name. By default, function blocks automatically assign a program-scoped block tag when you insert the function block. To specify a program-scoped block tag named PID1, enter:

program: *program_name*.PID1

where *program_name* is the name of the program.

Configuring display properties

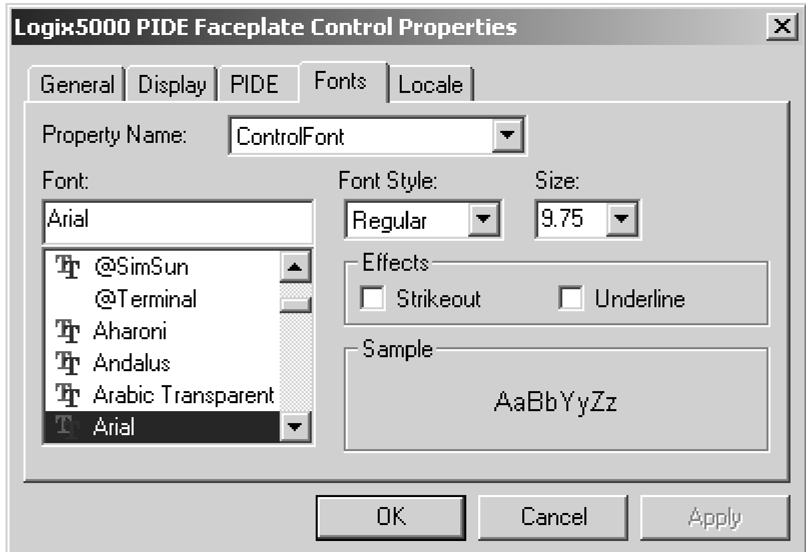
The display property page determines general screen properties.



Feature on property page:	Description:
Background Color	This button is the color of the faceplate's background color. default = light gray
Show Frame	This option turns on and off a 3-dimensional frame to the control. This allows the user to separate the control from other items that may be on the display. default = checked

Configuring font properties

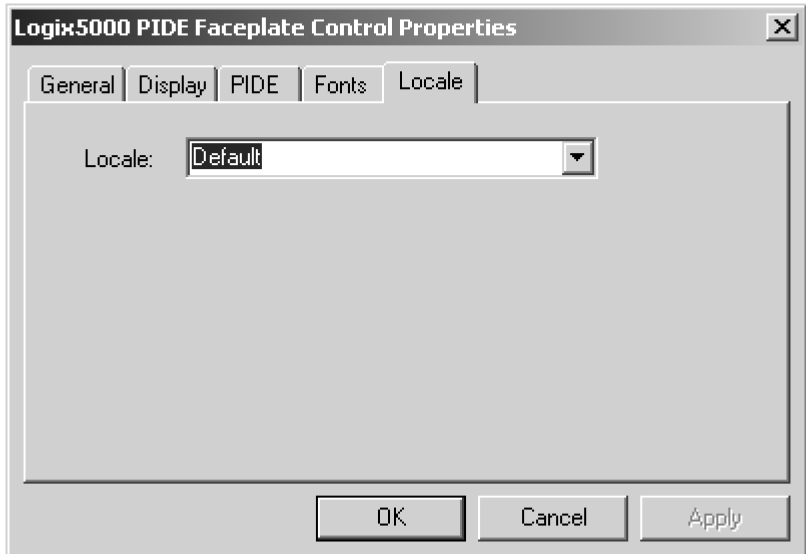
The fonts property page determines the fonts that appear on the faceplates. Configure a ControlFont to be used in the main part of the faceplates and a MinorFont font to be used in scales and other minor portions of the faceplates.



Feature on property page:	Description:
Property Name	Use this pulldown to select the font to configure. Select ControlFont or MinorFont. Default = ControlFont
Font	Select the font for the control. The list contains all available fonts on the system. Default = Arial
Size	Configure the point size of the font. Default ControlFont = 10.5 points Default MinorFont = 8.25 points
Effects	Select whether to underline and/or strikeout the font. Default = both unchecked

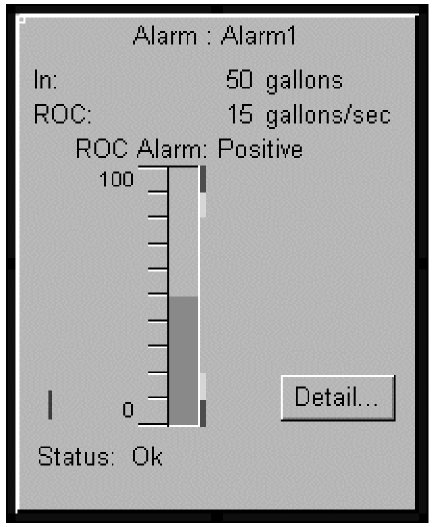
Configuring location properties

The locale property page determines language requirements.

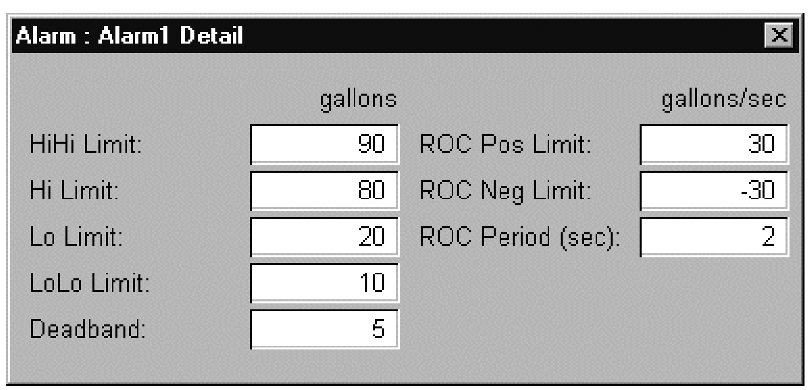


Feature on property page:	Description:
Locale	Select the language: • English • Portuguese • French • Italian • German • Spanish

ALM Control

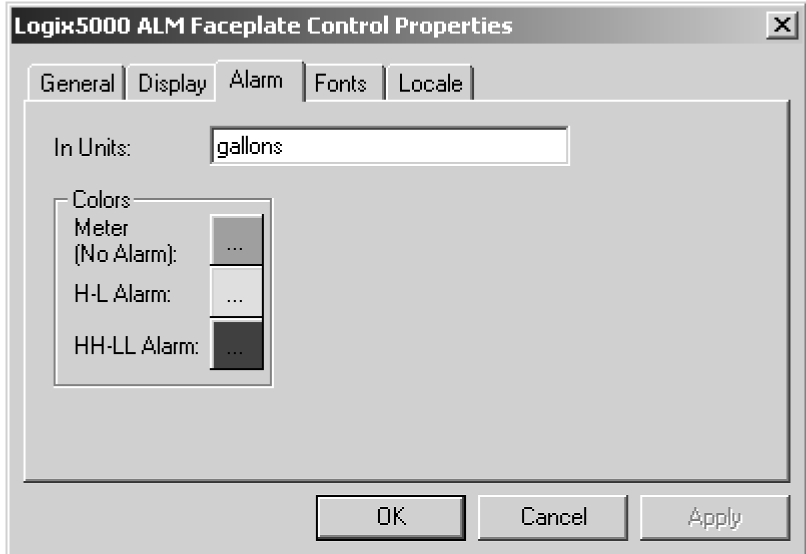


Feature on control:	Displays the:
In	current In Value.
Rate Of Change (ROC)	value of the ROC. If either the ROCPosAlarm or ROCNegAlarm values are set, the text color turns red. A tooltip is shown with the text of “Rate Of Change” when the cursor points to the control.
Alarm Bar Meter	In value of the block as it relates to the Alarm Limits of the block. If either the HAlarm or LAlarm values are set, the bar color is yellow. Likewise if either the HHAlarm or LLAlarm value are set, the bar color is red. If there are no alarms, the bar color is green.
Alarm Marking Bars	values of HHLim, HLim, LLim, and LLLim. The HHLim and LLLim bars are red, the HLim and LLim bars are yellow.
Alarm Meter Scale	scale of the alarm bar. The high part of the scale = HHLim + Deadband. The low end of the scale = LLLim – Deadband.
Detail Button	Detail Dialog pop-up.



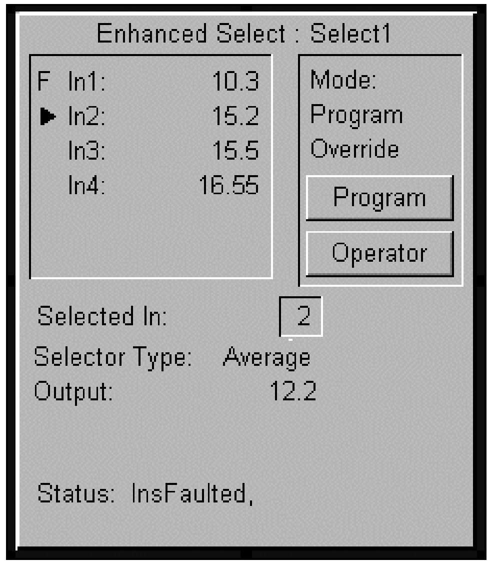
Status	all the status bits that are set in the block. If no bits are set, the status displays “OK”.

The ALM control has this additional property page.



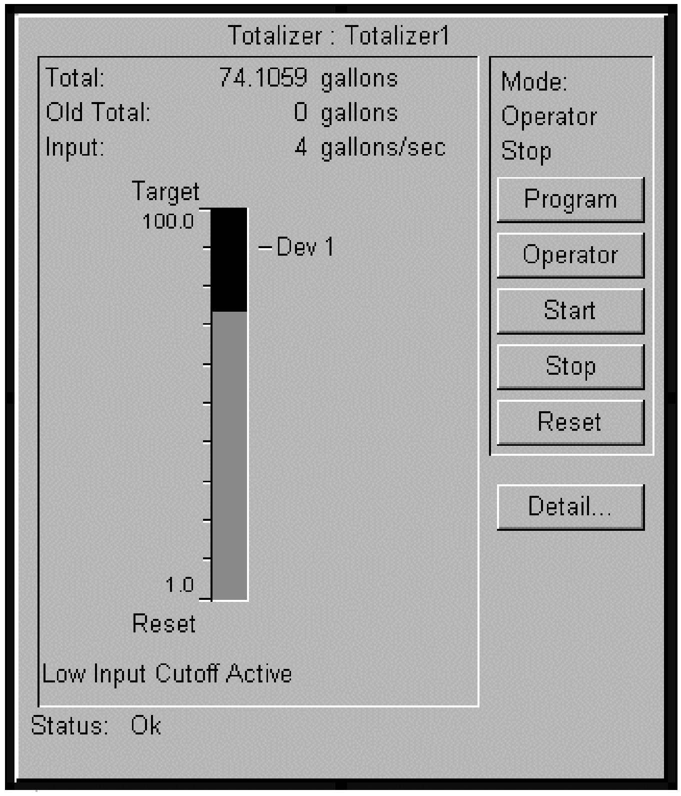
Configure this property:	To specify the:
In Units	units for the In field on the control.
Meter Color	color of the meter bar when no alarms are current.
H-L Color	color of the meter bar when the instruction is in either the Low or High alarm state.
HH-LL Color	color of the meter bar when the instruction is in either the Low-Low or High-High alarm state.

ESEL Control

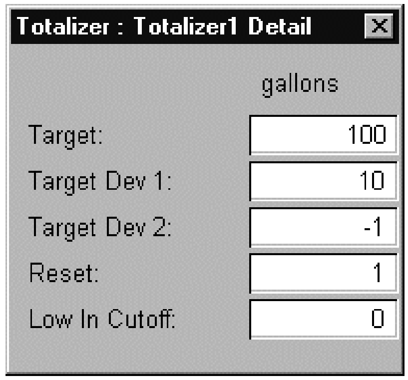


Feature on control:	Displays the:
Mode	mode of the block.
Input	inputs to the block. The number of displays (1-6), depends on the number of InsUsed.
Fault Indicator	the letter "F" to the left of the input display if the particular input is faulted.
Selected Indicator	triangle to the left of the input display indicates the selected input.
Program Button	OperProgReq is set when you click this button.
Operator Button	OperOperReq is set when you click this button.
Selected In	value of SelectedIn.
Selector Type	select mode.
Output	value of Out.
Status	all the status bits that are set in the block. If no bits are set, the status displays "OK".

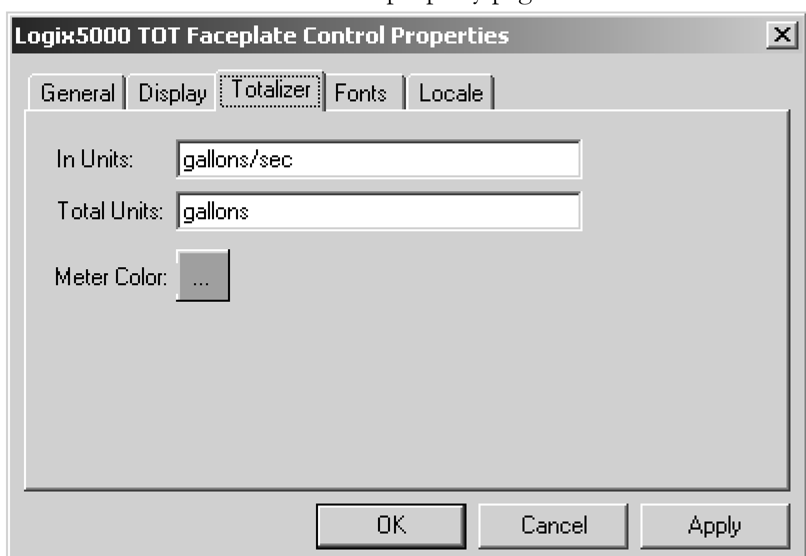
TOT Control



Feature on control:	Displays the:
Mode	mode of the block.
Total	value of Total.
Old Total	value of the previous Total.
Input	value of In.
Total Meter	range of Total values.
Target Dev1 and Dev2 Tick Marks	values of TargetDev1 and TagetDev2.
Total Scale	scale of the total meter. The high part of the scale = Target. The low end of the scale = Reset.
Program Button	OperProgReq is set when you click this button.
Operator Button	OperOperReq is set when you click this button.
Start Button	OperStartReq is set when you click this button.
Stop Button	OperStopReq is set when you click this button.
Reset Button	OperResetReq is set when you click this button.

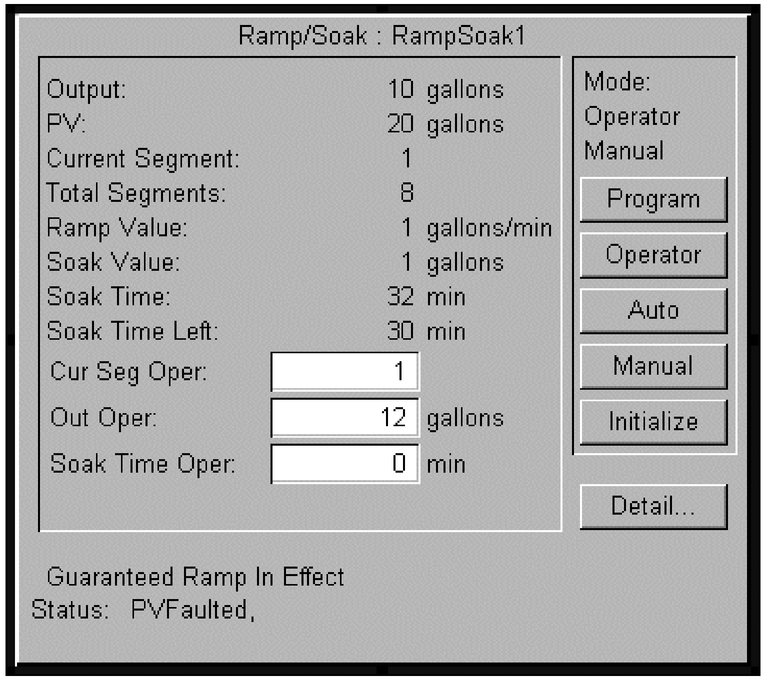
Feature on control:	Displays the:
Detail Button	Detail Dialog pop-up. 
Low Input Cutoff Active	statement “Low Input Cutoff Active” only when the LowInCutoffFlag is set.
Status	all the status bits that are set in the block. If no bits are set, the status displays “OK”.

The TOT control has this additional property page.



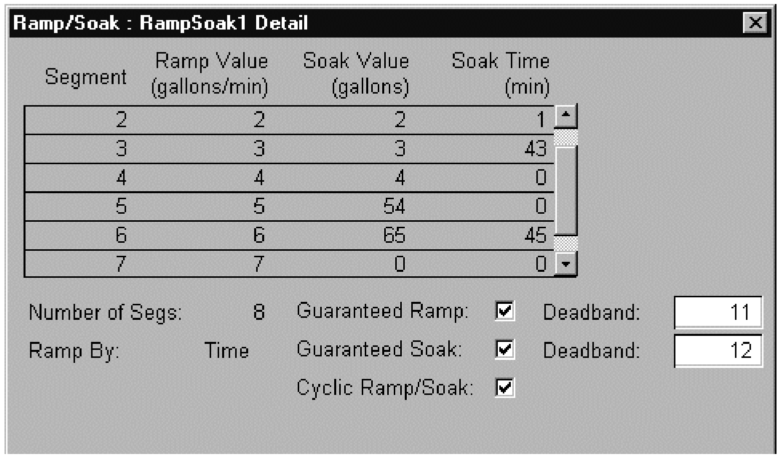
Configure this property:	To specify the:
In Units	units for the In field on the control.
Total Units	units for the Total and Old Total fields on the control.
Meter Color	bar color of the meter.

RMPS Control



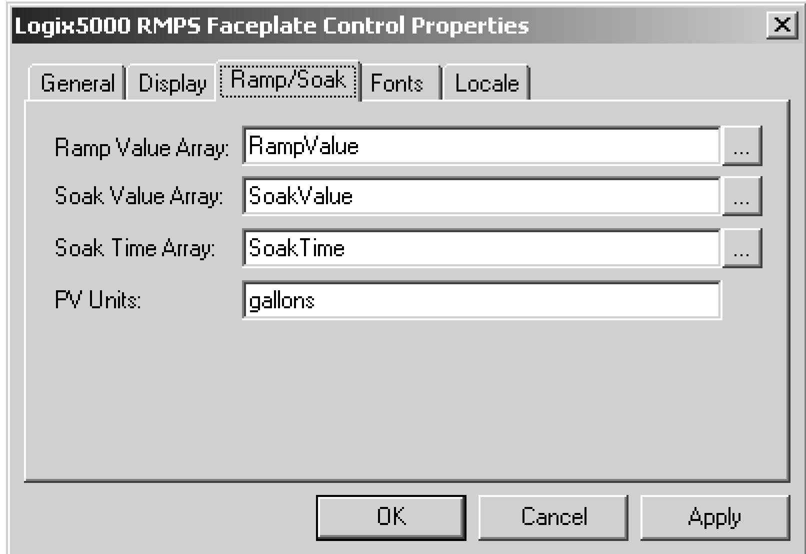
Feature on control:	Displays the:
Mode	mode of the block.
Output	value of Out.
PV	value of PV.
Current Segment	value of Current Segment.
Ramp Value	value of RampValue[ ] for the current segment.
Soak Value	value of SoakValue[ ] for the current segment.
Soak Time	value of SoakTime[ ] for the current segment.
Soak Time Left	value of SoakTimeLeft.
Program Button	OperProgReq is set when you click this button.
Operator Button	OperOperReq is set when you click this button.
Auto Button	OperAutoReq is set when you click this button.
Manual Button	OperManualReq is set when you click this button.
Initialize Button	Initialize is set when you click this button. This button is only enabled when the block is in the Operator Manual mode.

Feature on control:	Displays the:
Detail Button	Detail Dialog pop-up.



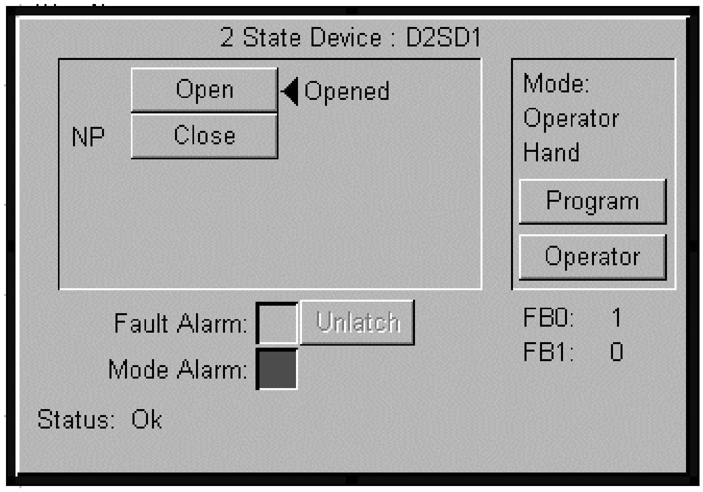
Feature on control:	Displays the:
Cur Seg Oper	value of CurrentSegOper.
Out Oper	value of OutOper.
Soak Time Oper	value of SoakTimeOper.
Guaranteed Ramp or Soak in Effect	statement “Guaranteed Ramp in Effect” or “Guaranteed Soak in Effect” when the corresponding GuarRamp or GuarSoak bits are set.
Status	all the status bits that are set in the block. If no bits are set, the status displays “OK”.

The RMPS control has this additional property page.



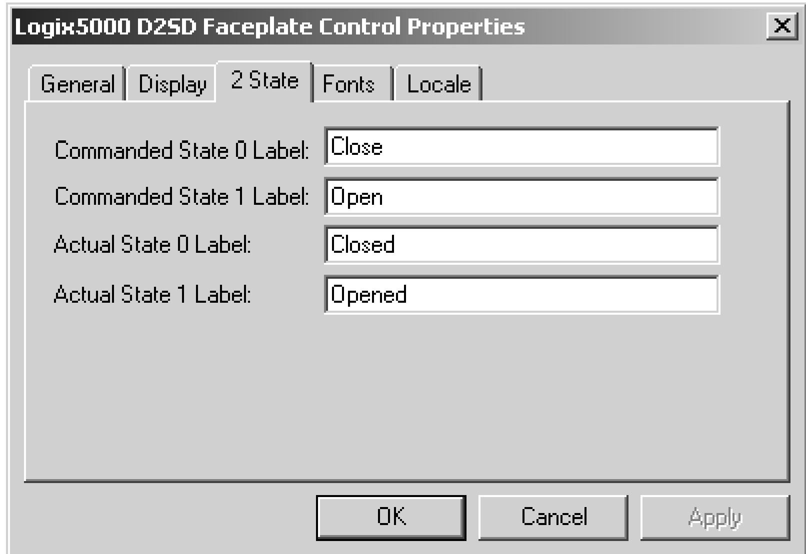
Configure this property:	To specify the:
Ramp Value Array	array in the controller that contains the ramp values.
Soak Value Array	array in the controller that contains the soak values.
Soak Time Array	array in the controller that contains the soak times.
PV Units	units that are displayed in the control.

D2SD Control



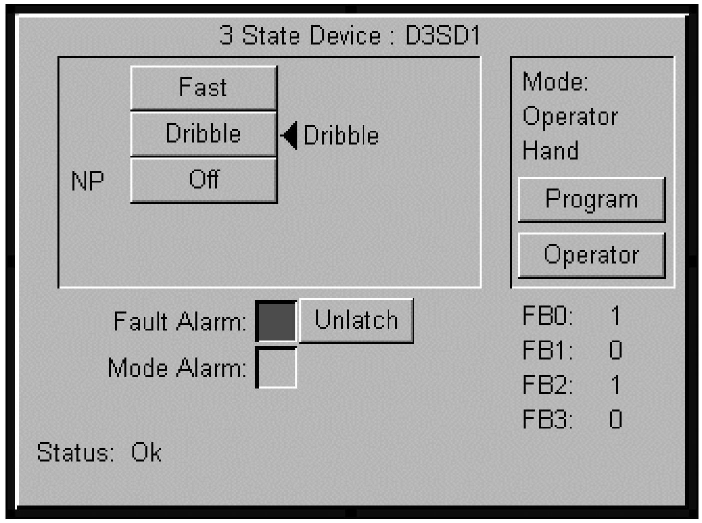
Feature on control:	Displays the:
Mode	mode of the block.
State Buttons	open or closed state of the Commanded State Label as defined in the control's property page. The top button sets Oper1Req. The bottom button sets Oper0Req. When clicked, the button sets the OperReq field for that particular state.
Ordered State Indicator	value of the Command Status by pointing to the request button for that state.
Actual State Indicators	status of the actual state. If DeviceStatus is set, the actual state is as configured for the given state.
Non-Permissive Indicator	letters "NP" to the left of the button if the StatePerm is not set for that state.
Fault Alarm Indicator	indicator if FaultAlarm is set.
Mode Alarm Indicator	indicator if ModeAlarm is set.
Unlatch Button	status of FaultAlmUnlatch. When this button is clicked, FaultAlmUnlatch is set. This button is only enabled when FaultAlarm and FaultAlmLatch are set.
Program Button	OperProgReq is set when you click this button.
Operator Button	OperOperReq is set when you click this button.
FB1	value of FB1.
FB0	value of FB0.
Status	all the status bits that are set in the block. If no bits are set, the status displays "OK".

The D2SD control has this additional property page.



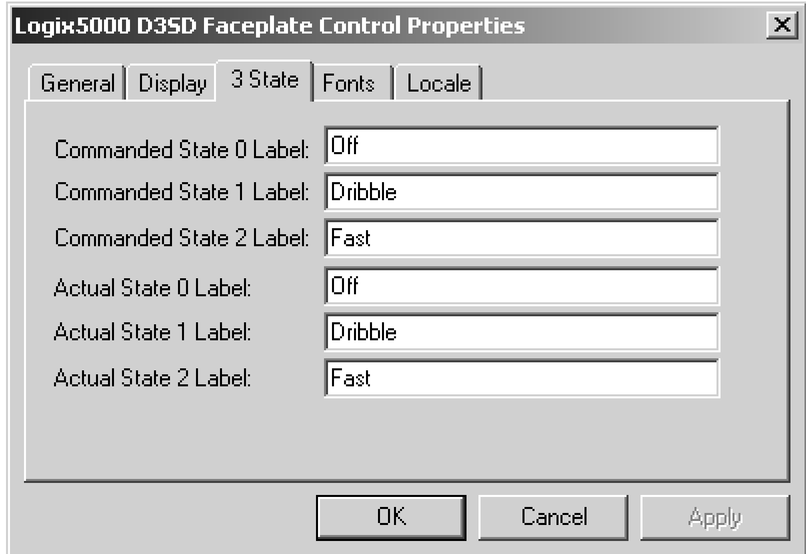
Configure this property:	To specify the:
Commanded State 0 Label	label for the Commanded State 0.
Commanded State 1 Label	label for the Commanded State 1.
Actual State 0 Label	label for the Actual State 0.
Actual State 1 Label	label for the Actual State 1.

D3SD Control



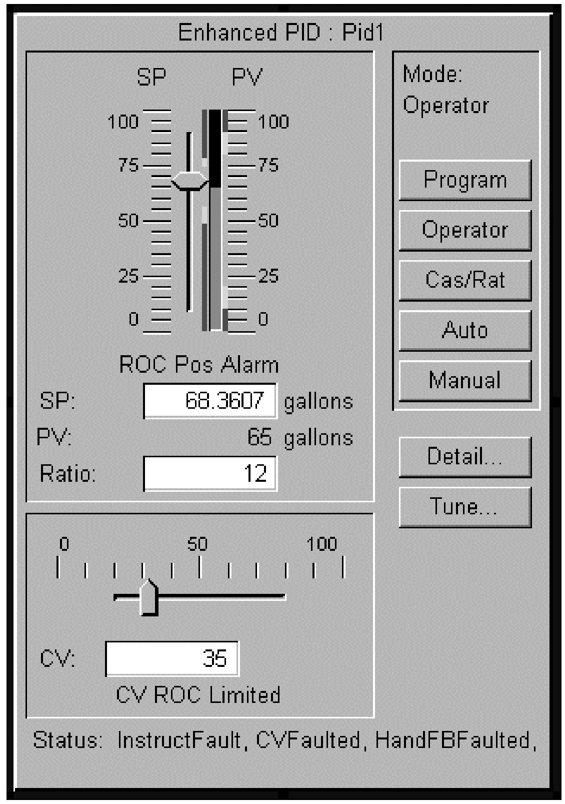
Feature on control:	Displays the:
Mode	mode of the block.
State Buttons	open or closed state of the Commanded State Label as defined in the control's property page. The top button sets Oper2Req. The middle button sets Oper1Req. The bottom button sets Oper0Req. When clicked, the button sets the OperReq field for that particular state.
Ordered State Indicator	value of the Command Status by pointing to the request button for that state.
Actual State Indicators	status of the actual state. If DeviceStatus is set, the actual state is as configured for the given state.
Non-Permissive Indicator	letters "NP" to the left of the button if the StatePerm is not set for that state.
Fault Alarm Indicator	indicator if FaultAlarm is set.
Mode Alarm Indicator	indicator if ModeAlarm is set.
Program Button	OperProgReq is set when you click this button.
Operator Button	OperOperReq is set when you click this button.
FB3	value of FB3.
FB2	value of FB2.
FB1	value of FB1.
FB0	value of FB0.
Unlatch Button	status of FaultAlmUnlatch. When this button is clicked, FaultAlmUnlatch is set. This button is only enabled when FaultAlarm and FaultAlmLatch are set.
Status	all the status bits that are set in the block. If no bits are set, the status displays "OK".

The D3SD control has this additional property page.

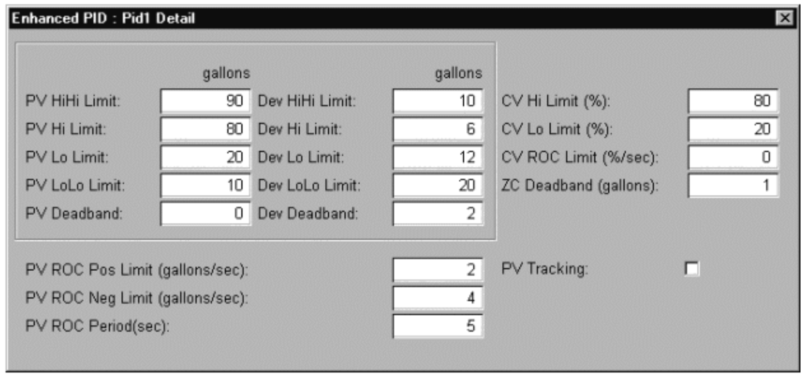
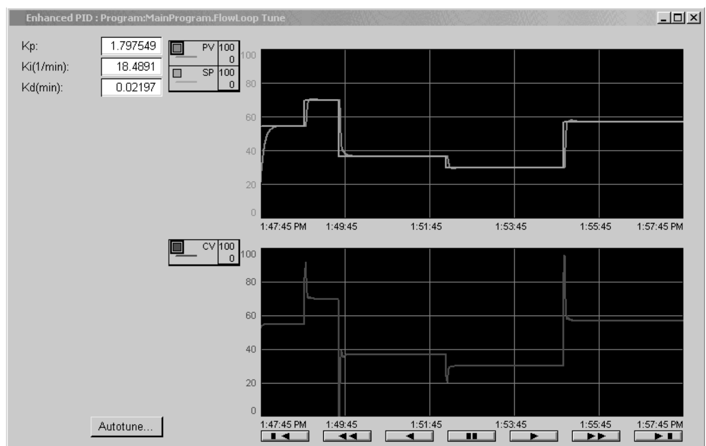
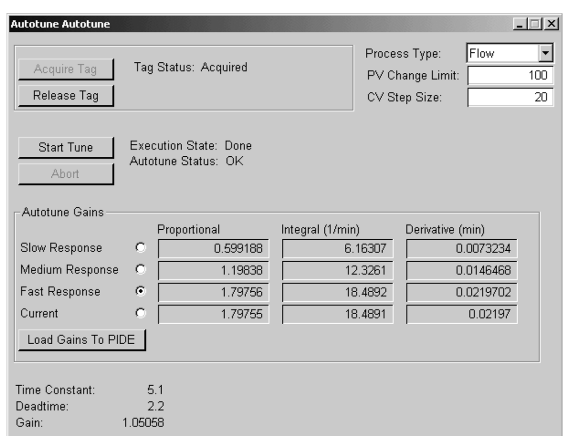


Configure this property:	To specify the:
Commanded State 0 Label	label for the Commanded State 0.
Commanded State 1 Label	label for the Commanded State 1.
Commanded State 2 Label	label for the Commanded State 2.
Actual State 0 Label	label for the Actual State 0.
Actual State 1 Label	label for the Actual State 1.
Actual State 2 Label	label for the Actual State 2.

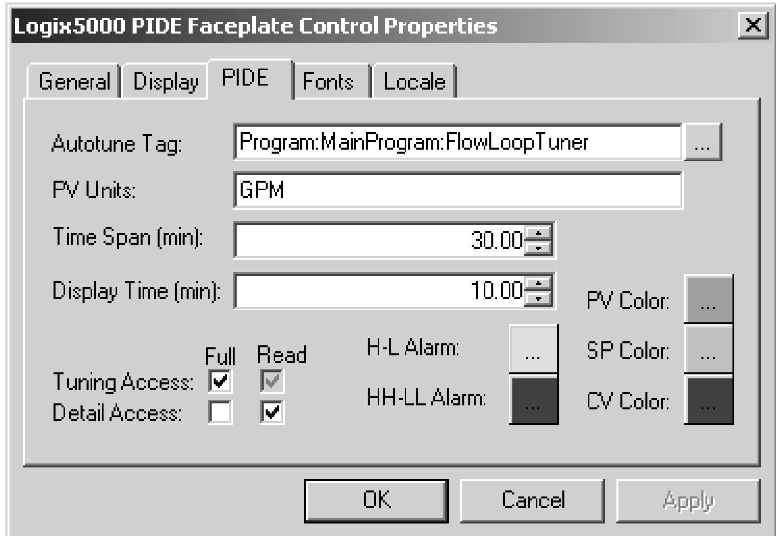
PIDE Control



Feature on control:	Displays the:
Mode	mode of the block.
PV Barmeter	value of PV. The limits of the barmeter are PVEUMax and PVEUMin.
Alarm Bars	limits for the Deviation and PV Limit Alarms. The Deviation Alarm Bars are on the left and move with the SP. The PV Limit Alarms are on the right and remain fairly static.
SP Slider	value of the SP. The limits of the slider are PVEUMax and PVEUMin. The slider is confined to SPHLimit and SPLLimit by its channel, which may not completely cover the PV Range.
ROC Alarm Indicator	status of PVROCPosAlarm and PVROCNegAlarm.
Ratio	value of Ratio. This display is only shown if both the AllowCasRat and UseRatio bits are set.
SP	value of the SP. The user may enter the new SP in this edit as well.
PV	value of PV.
CV Slider	value of CV. The limits of the slider are 0% to 100%.
CV	value of CV.
Program Button	OperProgReq is set when you click this button.
Operator Button	OperOperReq is set when you click this button.
Cas/Rat Button	OperCasRatReq is set when you click this button.

Feature on control:	Displays the:
Auto Button	OperAutoReq is set when you click this button.
Manual Button	OperManualReq is set when you click this button.
Detail Button	Detail Dialog pop-up. 
Tune Button	Tuning Dialog pop-up. 
Autotune Button	Autotuning Dialog pop-up (which you access from the Tune Dialog shown above). 
Status	all the status bits that are set in the block. If no bits are set, the status displays “OK”.

The PIDE control has this additional property page.



Configure this property:	To specify the:
Autotune Tag	PIDE tag
PV Units	string for the PV and SP units on the control.
Time Span	length of time that the values are kept for the trends.
Display Time	length of time that the values are displayed in the trends.
PV, SP, and CV Colors	color of the trend-line for each parameter.
Tuning Access Detail Access	level of access: full or read-only.
Alarm Colors	alarm colors represent the colors in the color bars. Alarm 1 Color represents the Lo or Hi alarms. Alarm 2 color represents the low-low or high-high alarms.

J

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Notes:

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Pub. Title/Type Logix5000™ Controllers Process Control and Drives Instructions Reference Manual

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Please complete the sections below. Where applicable, rank the feature (1=needs improvement, 2=satisfactory, and 3=outstanding).

Overall Usefulness	1 2 3	How can we make this publication more useful for you?
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If you experience a problem with a hardware module within the first 24 hours of installation, please review the information that's contained in this manual. You can also contact a special Customer Support number for initial help in getting your module up and running:

United States	1.440.646.3223 Monday – Friday, 8am – 5pm EST
Outside United States	Please contact your local Rockwell Automation representative for any technical support issues.

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Rockwell tests all of our products to ensure that they are fully operational when shipped from the manufacturing facility. However, if your product is not functioning and needs to be returned:

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Outside United States	Please contact your local Rockwell Automation representative for return procedure.

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